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Rahoitusteorian suuntautumisvaihtoehto

Forecasting Pulp and Paper Prices and Pulp Derivatives

Liiketaloustiede:
Rahoitusteorian
pro gradu-tutkielma
Kalle Saariaho
Syyslukukausi 1997

Laskentatoimen laitoksen
laitosneuvoston kokouksessa 5 / 9 19 97 hyväksytty
arvosanalla eximia cum laude approbatur
KTT Matti Keloharju KTT Vesa Puttonen

HELSINKI SCHOOL OF ECONOMICS AND BUSINESS ADMINISTRATION

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Title

Forecasting Pulp and Paper Prices and Pulp Derivatives

Subject

Finance

Level	Month and year	Number of pages
Master's thesis	September 1997	126

Abstract

The Objective of the Research

The objective of the thesis can be divided in two sub-objectives. First and foremost, the study aims to create forecasting models for NBSK pulp, uncoated fine paper, uncoated magazine paper and newsprint prices for one to twenty-four months in the future. Secondly, the recently launched pulp derivatives and their use in hedging price changes and effect on spot price behaviour will be studied.

Sources of information and data

Time series for the econometric forecasting methods were obtained mostly from Finnish Forest Industries Federation, such as historical prices and pulp production, deliveries and inventories. Some widely used economic time series were from OECD reports. Pulp derivatives data were from FOEX and PULPEX internet pages. Literature and interviews were used for the theoretical part.

The Method of the Research

The forecasting models were based on the basic ordinary least squares linear regression using co-integration of some of the variables in addition.

The Findings

Of the used time series, OECD industrial production, pulp inventories and pulp deliveries were found to have the greatest forecasting power for almost all models. Other variables were also included when needed. The pulp inventories and deliveries were used mostly as co-integrating variables, while their changes were also included in short term models. The models were tested by recalculating them each month between February 1993 and February 1997, and then comparing the forecasts and realised price. According to these tests, the pulp forecasts are much more reliable than paper forecasts, which mostly is due to the data being closer to pulp than papers. The adjusted coefficients of determination were between 37% and 66% for pulp forecasts up to 12 months and paper three month forecasts, with longer periods the figures were less impressive. The direction of price change was forecast with approximately 80% accuracy on the aforementioned periods.

Pulp derivatives trading started on the first half of 1997; so far the volumes have been low. Pulp derivatives can be used to hedge also paper prices, and it was found that for NBHK pulp the optimal hedge ratio is above 1.0, while for paper grades it is between 0.3 and 0.7. The evidence of whether derivatives trading increases or decreases spot price volatility is mixed.

Keywords

Pulp, paper, price forecasting, derivatives

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1 INTRODUCTION

1.1 Pulp and Paper Prices and the Finnish Economy

The forest industry plays a key role in the Finnish economy. Together, the forest industry and forestry contribute around eight per cent of Finland's GNP. Most clearly the significance of the forest industry to the Finnish economy is seen in exports, as it provides some 34 per cent of total commodity exports (figure 1-1). Compared internationally (figure 1-2), forest industry exports per capita is the highest in the world. Furthermore, the fact that the forest industry requires a smaller import input than other export sectors makes it even more important, accounting for around half of Finland's net foreign currency earnings. (Key to the Finnish Forest Industry)

Figure 1-1: Finnish Exports by Main Branches in 1994 (source: Key to the Finnish Forest Industry, FFIF, p. 19)

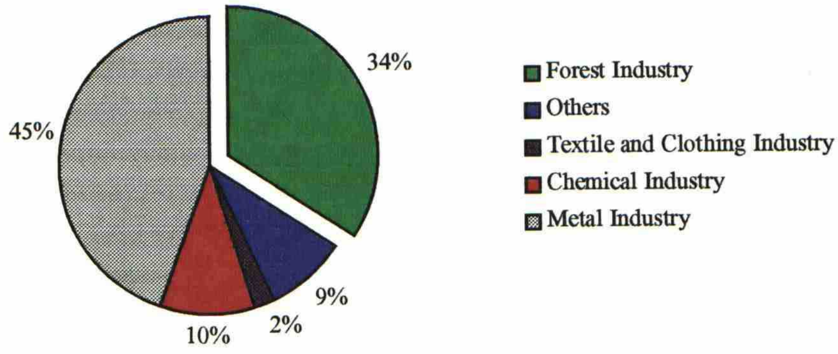
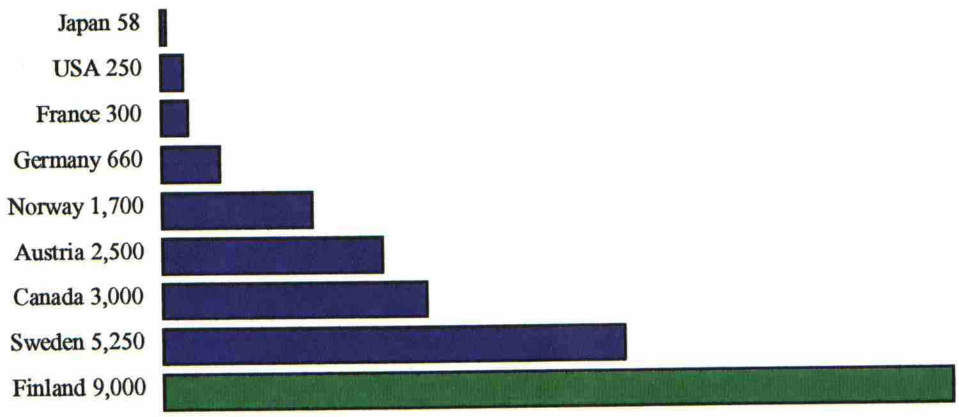
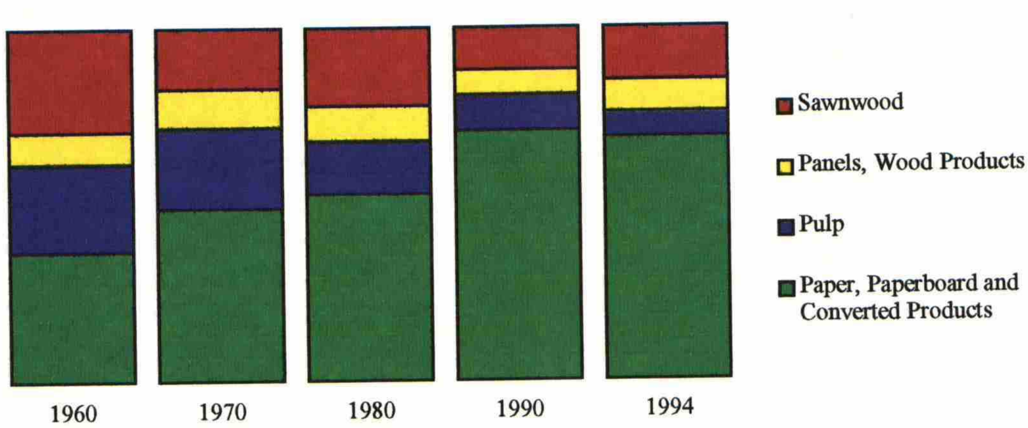


Figure 1-2: Forest industry exports per capita 1993, FIM (source: Key to the Finnish Forest Industry, FFIF, p. 8)



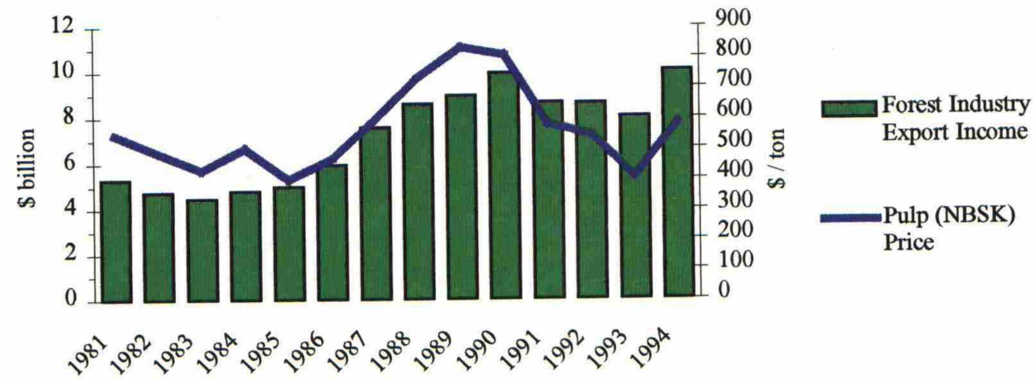
Of these exports, pulp and printing and writing paper accounted for 6.8% and 44.0%, respectively, in value (Metsäteollisuuden vuosikirja 95, p. 40). Although pulp's share of Finnish forest industry exports' value is rather small and has been diminishing for decades (figure 1-3), it must be noted that pulp is the primary raw material in printing and writing papers.

Figure 1-3: Finnish Forest Industry Exports by Main Product Groups (%) (source: Key to Finnish Forest Industry, FFIF, p. 19)



When pulp price changes, paper prices follow. Consequently, pulp price is a major factor determining forest industry's income, as figure 1-4 suggests. In addition, Finnish metal and engineering industry is to a notable extent dependent on world forest product cycles, as paper machines and forest machines are two of its main products. Thus, pulp price has a significant effect also on Finland's export income. Forecasting the pulp price (and paper prices) development would therefore be very valuable to economists at the industry and also economy level.

Figure 1-4: Finnish Forest Industry Export Income and Pulp (NBSK) Price 1981-1994 (sources: Metsäteollisuuden vuosikirja 1995 (income, p. 45), OECD Main Economic Indicators: Historical Statistics 1969-1988 and OECD Main Economic Indicators, Issues Jan 1989 - Mar 1997 (FIM/$), PaperInfo Oy (pulp price))



1.2 Overview of the World Pulp and Paper Markets

To be able to forecast pulp and paper prices the nature of the industry and markets must be known reasonably well. First of all, pulp production is a rather unique process with its own requirements. Furthermore, different paper grades are produced from more or less different raw materials, and are also more or less substitutable to each other. Finally, the integration of the pulp and paper production process plays an important part in determining both product groups' prices.

1.2.1 Different Pulp Grades and Pulp Production Processes

Although pulp is used in other products, such as synthetic fibres, plastic, lacquers, even explosives (FAO Yearbook of Forest Products 1981-1992), its most important use is as a raw material for paper. There are many different grades of pulp, of which the most important to this study are shortly described below.

Chemical pulp is produced by dissolving the lignin that binds the wood fibres together away using chemicals and heat. There are two basic methods to accomplish this: sulphate pulping uses an alkaline cooking liquor and sulphite pulping an acid cooking liquor. Of these sulphite pulp is no longer produced in Finland, although it was the main method until the 1980's. The raw material for chemical pulping is debarked softwood, i.e., spruce or pine, or hardwood (birch in Finland) in the form of chips.

After cooking with the liquor the product is brown and has to be bleached, if it is to be used to make white paper. Also unbleached pulp is available. Softwood pulp has many uses, but most of it is used as reinforcement fibre in papermaking, giving the paper greater strength and improving its runnability on the paper machine. Birch pulp is used mainly in the production of woodfree[1] papers, improving the paper's printing characteristics and its runnability in printing presses, copiers and non-impact printers.

Northern Bleached Softwood Kraft (NBSK) is bleached, chemical sulphate pulp made of coniferous woods, spruce and pine. **Northern Bleached Hardwood Kraft (NBHK)** is like NBSK but made of non-coniferous woods, mostly birch. The northern countries, also called the NORSCAN region, in this context are Canada, Finland, Norway, Sweden and the USA. As trees grow slower in the north, the fibre, pulp and finally paper are stronger and considered to be of better quality to most purposes than e.g. South American respective products.

Mechanical pulp is mostly made from fresh spruce, even though other woods can also be used. In the process the wood fibres are separated from each other by physical force. Mechanical pulp can be bleached or left unbleached, and is used to make printing papers because it gives the paper good printing properties. (Key to the Fin-

1 The slightly misleading term "woodfree" indicates that the paper contains no mechanical pulp.

nish Forest Industry, FFIF, pp. 50-51, and FAO Yearbook of Forest Products 1981-1992, p. xii)

Other less used pulp grades include various semi-chemical and dissolving pulps, which are actually special cases of the above, and pulp made of other fibres such as grasses, hemp, or textile wastes (FAO Yearbook of Forest Products 1981-1992, p. xii).

Pulp is produced in mills, and in 1994 there were some 9,100 pulp mills in the world. However, of these approximately 8,000 are estimated to be in China, which produces around twice the amount of pulp Finland does. In 1994, Finland's 43 pulp mills produced approximately ten million tonnes of pulp. The world's largest pulp producers and their paper production are listed in table 1-1. (Pulp and Paper International Annual Review, July 1995)

Table 1-1: The world's top 10 pulp producer countries and their pulp and paper and board production in 1,000 tonnes 1994 (source: Pulp and Paper International Annual Review, July 1995)

	Pulp	Paper and Board
USA	58,724	80,656
Canada	24,547	18,316
China	17,054	21,354
Sweden	10,867	9,354
Japan	10,579	28,527
Finland	9,962	10,910
Brazil	6,106	5,698
CIS	3,313	4,826
France	2,787	8,678
Norway	2,344	2,148

However, total production is not a relevant factor for pulp price. Most of the production is integrated, i.e., the pulp producer uses the pulp in its own paper production. Over 80% of pulp produced in the USA, Finland, and Sweden goes directly to the producers' own paper mills. Globally, some 20% of pulp is estimated to be so called market pulp, which is sold forward to other paper producers. (Yrjö-Koskinen

June 27, 1996). According to PULPEX (http://www.PULPEX.com), pulp production in 1996 totalled 180 million tonnes, of which 48 million tonnes (27%) was market pulp, but this figure includes pulp exported to the exporter's own factories abroad. Of market pulp, Nordic softwood (NBSK) represents approximately one third, as shown in table 1-2.

Table 1-2: Production of market pulp by pulp grades in 1996 (1000 tonnes, source: http://www.PULPEX.com)

Pulp Quality	Production	%
Nordic Softwood	16,320	34%
Nordic Hardwood	4,800	10%
Southern Softwood	5,760	12%
Southern Hardwood	7,200	15%
Eucalyptus	7,680	16%
Radiata	1,920	4%
Other	4,320	9%
Total	48,000	100%

Market pulp production is quite fragmented, as the ten largest market pulp producers together produce approximately 28.5% of total production (table 1-3). The largest single producer, Weyerhaeuser, has a 4.5% share of world production. Most of the largest producers are also listed among the largest buyers of market pulp. Partly this is because all pulp exports are included in market pulp figures, even if the owner of the "buyer" paper mill is the same as the owner of the "seller" pulp mill, and the pulp is actually integrated. For example, UPM-Kymmene, the second largest producer according to the table, is actually using virtually all the market pulp it is supposed to be producing.

Shocks in paper demand may cause the pulp price to fluctuate wildly. If paper demand falls, paper mills may be shut down to wait for better times. Pulp mills, however, are not as often shut down. Especially in the USA, pulp producers are reluctant to shut down pulp mills. In autumn 1995, integrated paper production fell by 20% due to decreasing demand, which caused the available supply of market pulp to grow by many times as much. At the same time demand for market pulp diminished as paper prices were low and paper producers' inventories full. This behaviour explains part of the volatility of pulp prices. (Haavisto July 5, 1996)

Table 1-3: The ten largest market pulp producers in the world and their market pulp production (1000 tonnes, source: http://www.PULPEX.com), and share of world total market pulp production in 1996

Company	Production	% of total market pulp production
Weyerhaeuser	2,159	4.5%
UPM-Kymmene	2,000	4.2%
Georgia-Pacific	1,871	3.9%
International paper	1,575	3.3%
Stora	1,238	2.6%
Aracruz	1,042	2.2%
Sappi	1,000	2.1%
Stone Container	983	2.0%
Södra	911	1.9%
Arauco y Constitucion	898	1.9%
Total	13,677	28.5%

Moreover, ever tightening quality demands and increasing requirements by faster paper mills have led to very strict demands for pulp quality. It is not usually possible to just replace, say, Finnish hardwood kraft with Indonesian hardwood kraft. This is why also market pulp capacity is often sold a year or so in advance, and what makes deliverable pulp derivatives more difficult to use.

1.2.2 Paper Grades of the Study

Papermaking begins with the mixing together of chemical and/or mechanical pulp fibres and various additives. The components of this study's grades are presented in table 1-4. Softwood chemical pulp is normally used in all grades, but newsprint and magazine papers consist mainly of mechanical pulp. Also, by looking at figure 3-12 on page 42 and the figures following it, it can be seen that fine paper prices correlate better with softwood kraft prices than the other three grades' prices.

Table 1-4: Components of different paper grades (source: Key to the Finnish Forest Industry, FFIF, p. 52)

Newsprint	85-100%	Mechanical Pulp and Recycled Fibre
	0-15%	Bleached Softwood Chemical Pulp
Uncoated Magazine Paper (SC)	50-70%	Mechanical Pulp
	10-25%	Bleached Softwood Chemical Pulp
	15-30%	Filler
Coated Magazine Paper (LWC)	40-60%	Mechanical Pulp
	25-40%	Bleached Softwood Chemical Pulp
	20-35%	Filler and Coating Pigment
Uncoated Fine Paper	55-80%	Bleached Birch Pulp
	0-30%	Bleached Softwood Pulp
	10-30%	Filler
Coated Fine Paper		As Uncoated, Coatweight Varies

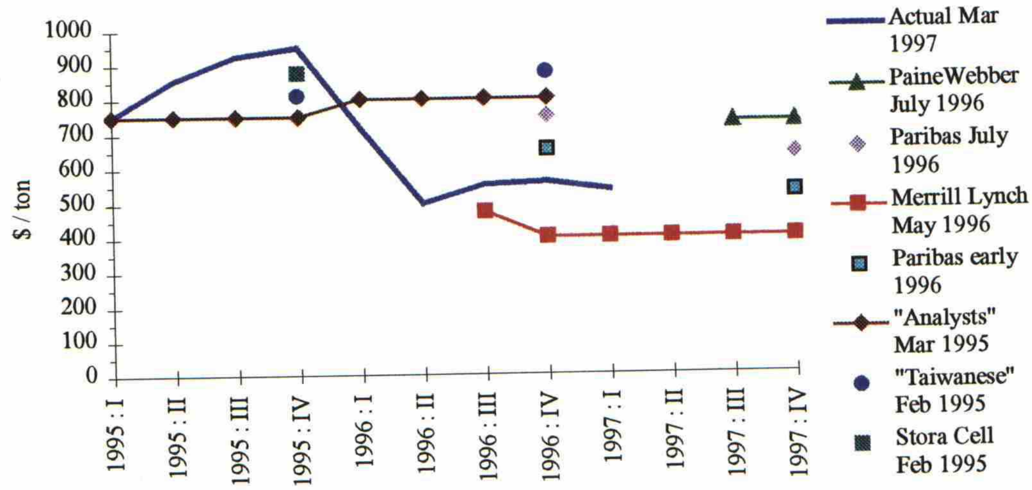
The different grades are to some extent substitutable. It should be obvious that coated grades are more expensive than uncoated ones, and usually also fine papers cost more than magazine papers, while newsprint is the cheapest grade. If the price of a better quality grade would drop below the price of a lower quality grade, demand of the better quality grade would rise and the price would follow. NBSK is used in all grades and NBHK in fine papers.

See *Appendix 1: Glossary* for a review of the special terms used in this study.

1.3 Recent Developments in Pulp and Paper Prices

During the last few years, pulp prices have been very difficult to forecast. Some forecasts are shown in figure 1-5. Forecasts made in early 1995 were not quite able to predict the strength of the rise in prices, and were extremely over-optimistic for prices in 1996. More recent forecasts by investment banks show a great discrepancy between them, as Merrill Lynch forecasts \$400, Paribas \$650, and PaineWebber \$730 for end-of-1997 price. To what extent any of these is correct remains to be seen. When examining the figure it should be noted that the forecasts were given at different points of time.

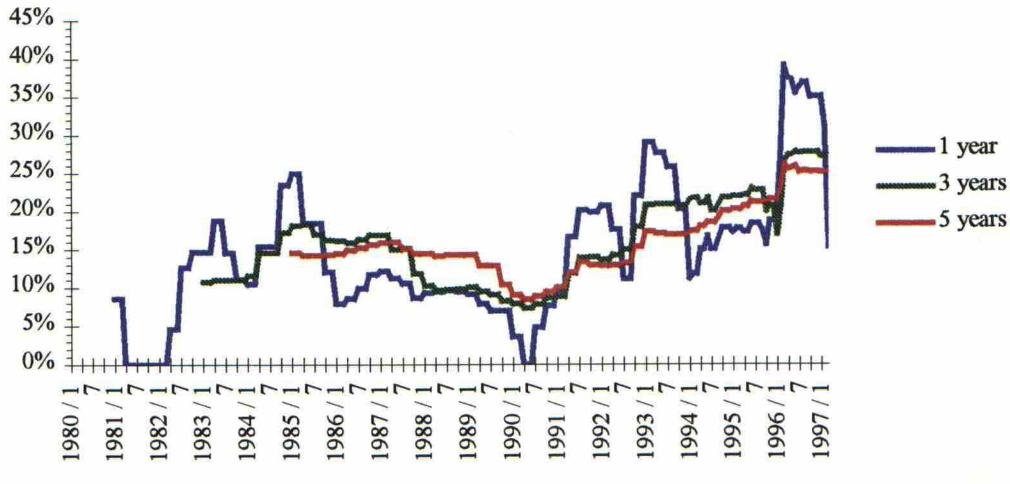
Figure 1-5: Some pulp price forecasts and dates of forecast vs. actual quarter's average price (sources: Actual - PaperInfo Oy, Paribas - Kauppalehti 5 July 1996, p. 9, ML - Kauppalehti 15 July 1996, p. 3, PW - Kauppalehti 23 July 1996, p. 7, SC - Dagens Industri 4 Jan 1995, p. 7, "Analysts" - World Paper Mar 1995, p. 4, "Taiwanese" - Commercial Times 23 Feb 1995, p. 14)



Price movements have been larger and faster than before (see figure 2-1, p. 13). The high volatility (figure 1-6) is of course a major concern to forest industry, as the growing risks cause expenses and make evaluating investment projects very difficult. As can be observed from the figure, volatilities for the past 1, 3, and 5 years have risen to 25%+ in 1996 from the below 10% level of 1990. The one year volatility peaked at 39% in March 1996, but as the price development after that has been more stable, the volatility has dropped to 15% in March 1997.

The increased volatility, despite the last 12 months' stable prices, surely is one of the main reasons why exchange-traded pulp derivatives are starting to interest pulp and paper buyers and sellers once again. Standardised pulp derivatives were first brought on sale by Montreal Exchange in the mid-1980's, but they were soon discontinued due to low volumes. Pulp differs from most exchange-traded commodities in two important aspects. Firstly, settlement can not easily be made by delivery of the physical product, because some 80% of capacity is sold beforehand and there are relatively big quality differences, as previously noted. This problem, mostly, caused the failure of Montreal Exchange. Second, for clearing in cash, the clearing price is rather difficult to set as there has been no one world-price nor is physical pulp traded on any exchange. (Lindeberg June 11, 1996)

Figure 1-6: Pulp (NBSK) yearly price volatility[2] for 1, 3, and 5 years



Despite these problems, the Finnish Options Exchange (FOEX) has launched pulp derivatives based on their own PIX pulp price index in February, 1997. PULPEX, a subsidiary of the Swedish derivative exchange OM, launched physical delivery-based products in May, 1997. Even though the start with derivatives has been slow and volumes small, many market participants and professionals are sure that pulp derivatives have come to stay. Still, it remains to be seen where and in what quantities pulp derivatives will be traded. (Lindeberg April 4, 1997)

One of the interesting features of pulp derivatives trading is that the trading will probably also affect pulp spot price. This issue will be discussed in section *4.5 Derivatives and Forecasting*, p. 100.

2 Yearly price volatility is calculated as the standard deviation of logarithmic monthly price changes multiplied by the square root of the number of observations in a year (12).

1.4 Scope and Objectives of the Present Study

The objective of this study can be divided in three sub-objectives. First and foremost, a forecasting model will be developed for NBSK pulp world prices using data available to Finnish forest industry. Short-term (1 to 6 months) and long-term (9, 12, 18 and 24 months) price forecasts will be generated. The econometric method used will combine OLS linear regression, error-correction and co-integration.

Second, forecasting models for three separate paper grades prices will be developed. These paper grades are newsprint, uncoated fine paper, and uncoated magazine paper. For these, Finnish export price in U.S. dollars will be forecast for 3, 6, 12, and 24 months. Especially for papers, but also for pulp, world prices differ within the grades as quality, availability and other differences affect the price. Hence, the forecasts will be for an average price.

While pursuing the first two objectives, graphical analysis of available forecasting factors will be presented to ease the understanding of the final models. Also coated fine paper and magazine paper will be examined in this analysis, although data were insufficient for generating models forecasting the price of the coatings.

Third, pulp derivatives and the effect of pulp derivatives trading on pulp price development will be discussed. The principles of hedging with futures and options will be described shortly, and the possibilities of hedging paper prices and company results with pulp derivatives examined. Optimal hedge ratios for the studied products will be estimated.

2 MATERIALS AND METHODS

2.1 Time Series Data

Data for time series analysis were collected from various sources. When comparing pulp and paper market data to, for example, data available for commodities traded in commodity exchanges, there are three fundamental differences. First, the data are not easily available, as there is no single source such as an exchange, where the quantities and prices could be collected. Second, the data available are not continuous, but consist of monthly, quarterly or yearly observations. Third, almost all data are aggregates or averages, as the products are not strictly standardised, and many values have to be at least partly estimated.

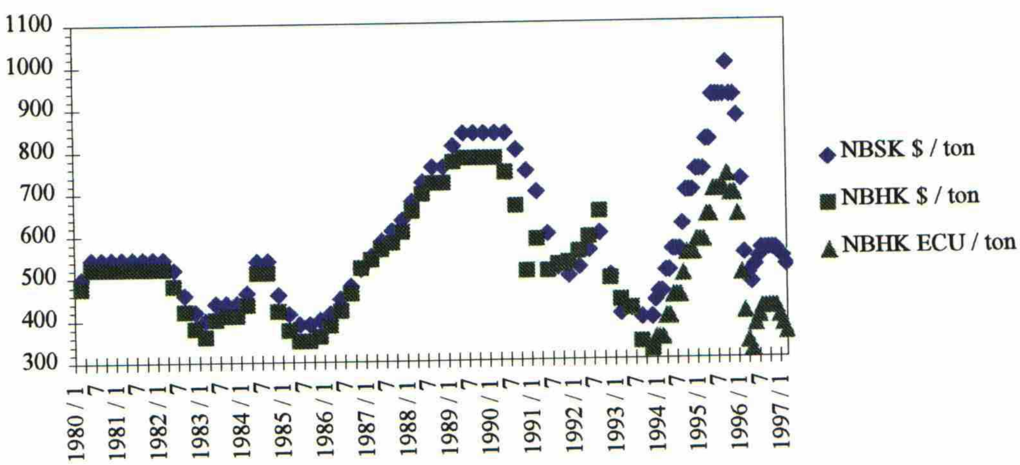
As the pulp and paper markets are changing all the time, a special emphasis was placed on keeping the data as recent as possible. Also, to be able to get statistically significant results and more accurate short term forecasts, the frequency of the data was kept as high as possible. Thus, monthly values for most variables are used. Unfortunately, there are no monthly data for pulp prices until after January 1994.

2.1.1 Pulp Data

For a short description of the world pulp markets, see the previous section. All pulp data were obtained from PaperInfo Oy, a subsidiary of Finnish Forest Industries Federation.

Pulp price data consist of series for NBSK and NBHK (figure 2-1). Both series have observations quarterly before year 1994 and monthly from January 1994. Before 1994, it was a usual convention among pulp sellers to set a quarterly price and (apart from special price reductions) hold it for the three months.

Figure 2-1: NBSK and NBHK pulp price data 1980:I-1997 (source: PaperInfo Oy)



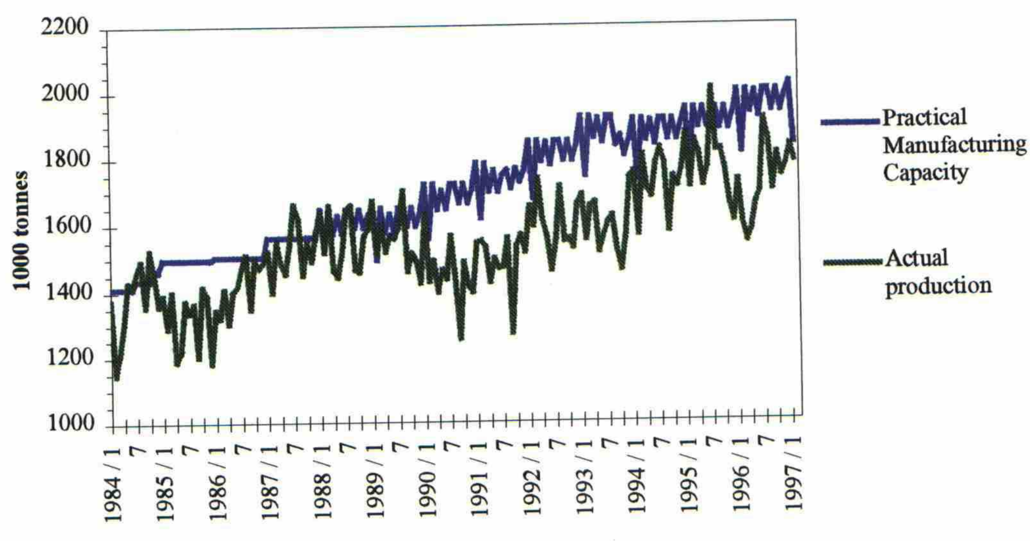
The data for NBSK are in U.S. dollars for the complete time period, while for NBHK observations before 1994 are in U.S. dollars and starting 1994 in ECUs. For analysis, ECUs were converted to dollars.

The two pulp qualities are not very different from each other, and can be to a certain extent substituted by each other, so it is natural that their prices correlate strongly. The data are clearly highly cyclical; during the relatively strong upswing in world economy, pulp prices rose steadily from the second quarter of 1985 to the second quarter of 1989, and then, as the recession hit, they fell until the end of 1994. The smaller peak in 1991-1992 was partly due to a 32-day strike in Canada in June-July 1992, which led to a significant (500,000 tonnes of NBSK) cut in supply (Paper, Nov 1992, p. 26). The stockpiling because of a strike threat before the strike drove prices up (Teräs July 3, 1996). There is an apparent outlier observation in NBHK price in the last quarter of 1990.

The next cycle was a lot shorter and stronger than the previous one. Starting January 1994, prices soared and were more than doubled in October 1995. At that time, many analysts forecast that prices (of NBSK) would continue to rise to the level of $1200-1300, and that the situation had fundamentally changed - e.g., the old inventory-price relationship would no longer hold (Haavisto July 5, 1996). However, the first quarter of 1996 saw the fastest pulp price drop in history, and by May 1996, prices were halved from October highs. Figure 1-7 already showed the change in price volatility.

Two important factors on the supply side of pulp markets are manufacturing capacity and actual production of pulp (figure 2-2). As pulp production is very capital intensive, there is a strong incentive to run the mills almost continuously. But, if prices fall due to excess supply, mills are not very profitable. At these times they may stop production for repairs and servicing, which cuts down supply and may help bringing prices back to higher levels. (Teräs July 3, 1996)

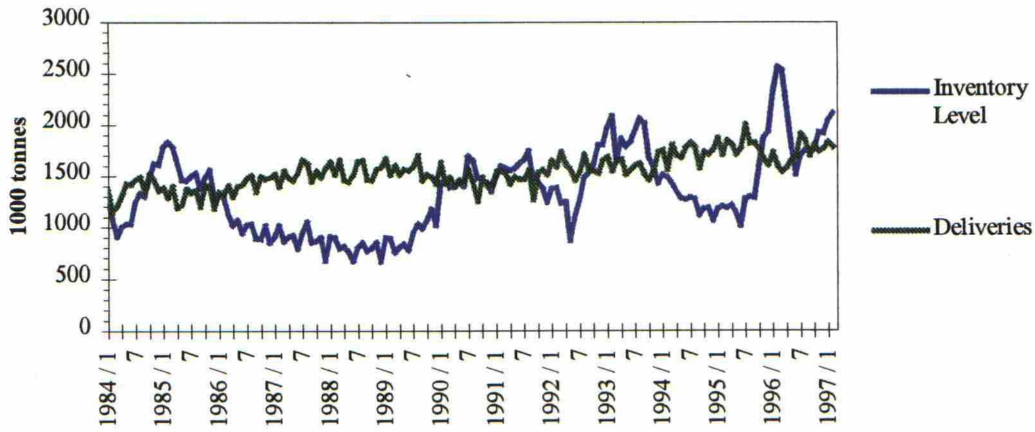
Figure 2-2: NORSCAN chemical paper grades market pulp practical manufacturing capacity and actual production 1984:1-1997:2 (source: PaperInfo Oy)



Practical manufacturing capacity (PMC) is an estimate of potential production of chemical paper grades market pulp in the NORSCAN region. It has a clearly linear trend, while actual production fluctuates more strongly below PMC levels. For actual production, monthly observations are expert estimates, as some U.S. data in 1993 and monthly data (quarterly data have been obtained, however) from Sweden after January 1994 are not available. However, the resulting errors can be assumed to be insignificant.

A well known supply side variable is producer inventory level. To simplify, rising inventories implicate that supply is higher than demand, and vice versa. Deliveries to pulp buyers, on the other hand, is a demand side variable. Both are presented in figure 2-3, inventory level being an end-of-month observation.

Figure 2-3: NORSCAN chemical paper grades market pulp producer inventory level and deliveries 1984:1-1997:2 (source: PaperInfo Oy)



As was the case with actual production, observations after 1993 are expert estimates, except for end-of-quarter inventory levels, which are actual.

The connection between actual production, deliveries, and inventory level is obvious. If production exceeds deliveries, inventories should grow by the same amount, and vice versa. However, there were some small discrepancies in the data. These were mostly from the 1980's and were left untouched, as they were estimated to be insignificantly small and difficult to correct.

To summarise, pulp data cover NBSK and NBHK prices, and NORSCAN paper grades market pulp potential manufacturing capacity, actual production, producer inventory levels, and deliveries. The data are monthly, except for prices before 1994.

2.1.2 Paper Grades Data

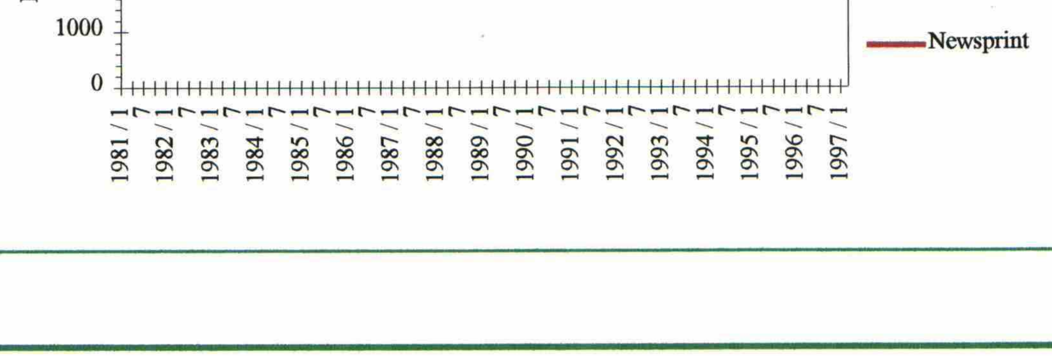
Data on paper production and consumption world-wide are very difficult to obtain on a monthly or even quarterly basis. FAO[3] surveys and Pulp and Paper International magazine publish yearly estimates of world pulp and paper trade, capacities, etc., but these are rather useless for forecasting purposes.

Finnish export prices for the five paper grades are, however, available as customs statistics. The following data were obtained from the Finnish Forest Industries Federation.

Monthly prices for newsprint, uncoated magazine paper (supercalendered, SC), and coated magazine paper (lightweight coated, LWC) are presented in figure 2-4. For coated magazine paper, no data were available for the years prior to 1988.

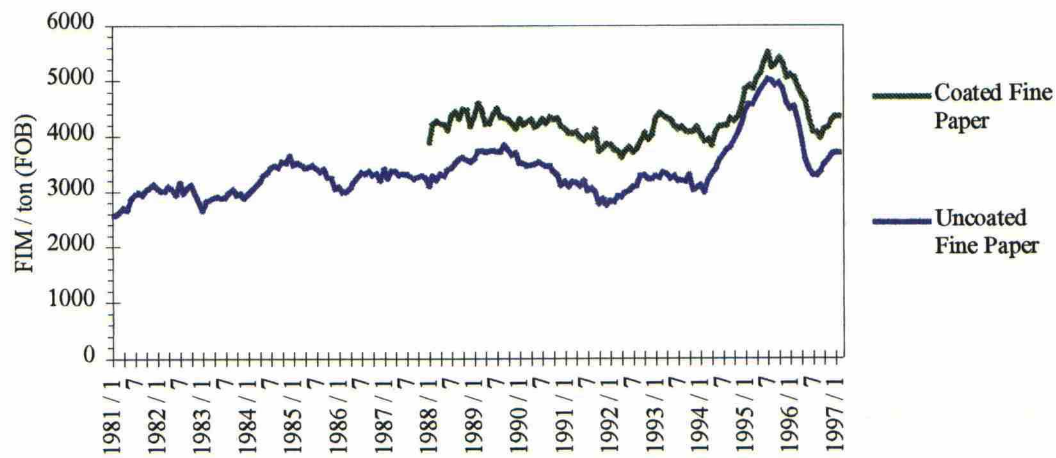
It is easy to see that paper prices (at least in FIM) are much less volatile than pulp prices. For analysis, exchange rate effect is of course removed by using U.S. dollar prices. Also it is obvious that these three paper grades' price changes are highly correlated, as explained in the overview of the markets before.

Figure 2-4: Finnish export prices of newsprint and uncoated magazine paper (SC) 1981:1-1997:2 and coated magazine paper (LWC) 1988:1-1997:2 (source: FFIF)



Prices for fine papers are displayed in figure 2-5. Again, for the coated grade, data were available only after year 1988. Correlation is easily observed here, too, and it seems that changes in uncoated fine paper price may lead coated fine paper price changes for a month or two. The volatility of fine paper prices is clearly higher than that of magazine papers and newsprint, but not as high as pulp's.

Figure 2-5: Finnish export prices of uncoated fine paper 1981:1-1997:2 and coated fine paper 1988:1-1997:2 (source: FFIF)

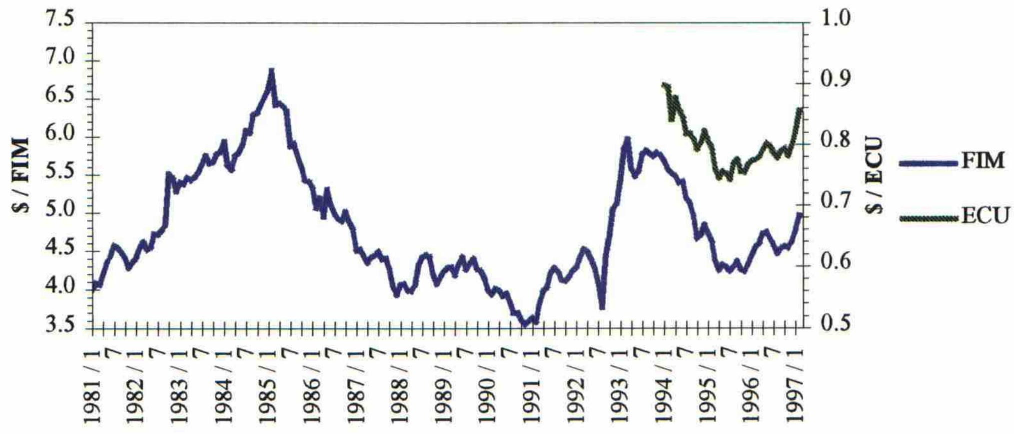


2.1.3 Economic Indicators Data

Some economic indicators were selected for data manipulation, trend removal, and forecasting purposes. Currency exchange rates for ECU and Finnish mark against U.S. dollar (figure 2-6) were used to transform all non-dollar prices to "world prices" in U.S. dollars. Even if slightly different prices are used in, say, France, Italy, and Germany, it can be argued that the dollar price is the best approximate for the "true price" (Tahvanainen June 12, 1996).

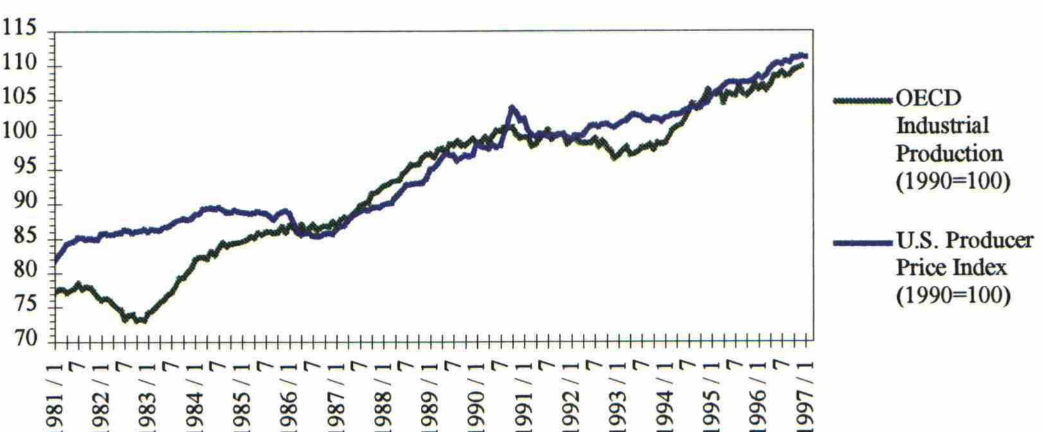
[3] Food and Agriculture Organization of the United Nations

Figure 2-6: Finnish mark (1981-1997) and ECU (1994-1997) exchange rates against U.S. dollar, end-of-month observations (sources: OECD Main Economic Indicators: Historical Statistics 1969-1988, OECD Main Economic Indicators, Issues Jan 1989 - Mar 1997, SOM Ltd (March 1997 rates))



U.S. producer price index (figure 2-7) is used to remove the upward-sloping trend of dollar price data. The resulting real pulp and paper prices are then used in forecasting, thus eliminating the effect of inflation.

Figure 2-7: U.S. producer price index 1981-1997 and OECD industrial production index (seasonally adjusted) 1981-1997 (sources: OECD Main Economic Indicators: Historical Statistics: Prices, Labour and Wages 1962-1991, OECD Main Economic Indicators: Historical Statistics 1969-1988, OECD Main Economic Indicators, Issues Jan 1989 - Mar 1997)



OECD industrial production index (figure 2-7) is utilised as a proxy for global business cycles, which seem to move closely with overall paper demand. The last two months of US producer price index and the last three months of OECD industrial production index were not available at the time data were obtained. For these months the last observation was used.

2.1.4 Basic Statistics

In table 2-1 are listed all input variables entered in the econometrics software used, Shazam v7.0. The eight characters long Shazam variable names are also shown to identify the variables in the next table, where space is more limited.

Table 2-1: Input variables and their number of observations, mean, standard deviation, variance, and minimum and maximum values

	NAME	N	MEAN	ST. DEV	VAR.	MIN.	MAX.
Month	**MONTH**	206	198820	496.57	246580	198001	199702
NBSK pulp price	**NBSK**	206	580.68	150.07	22522	390.00	1000.00
NBHK pulp price	**NBHK**	206	546.15	146.51	21465	320.00	972.22
Newsprint price	**NEWSPR**	194	507.46	113.94	12982	315.37	757.84
Unc. mag. paper price	**UMAGPAP**	194	604.57	129.92	16880	406.20	926.66
Coated mag. paper price	**CMAGPAP**	110	820.46	110.62	12236	647.74	1129.00
Unc. fine paper price	**UFINEPAP**	194	721.04	159.31	25380	493.71	1185.30
Coated fine paper price	**CFINEPAP**	110	966.18	150.28	22583	700.97	1297.90
NBSK potent. manuf. cap.	**PMC**	158	1700.80	176.62	31195	1411.00	2024.00
NBSK actual prod.	**ACTPROD**	158	1549.40	161.32	26025	1149.00	2007.00
NBSK deliveries	**DELIVER**	158	1544.10	176.12	31019	1220.00	2048.00
NBSK invetory level	**INVENTOR**	158	1344.00	397.60	158080	672.00	2569.00
OECD industrial prod.	**OECDIP**	206	91.82	10.80	116.59	73.16	109.90
US producer price index	**USPPI**	206	94.26	9.13	83.39	73.27	111.40
FIM/USD exchange rate	**FIM**	206	4.7491	0.7613	0.5797	3.5600	6.8809

The correlation matrix presented in table 2-2 shows correlation between all variables used in forecasting. The strongest correlation exists between uncoated magazine paper price and newsprint price, while also NBSK and NBHK prices, and US producer price index and OECD industrial production are strongly correlated.

Table 2-2: Correlation matrix of variables used in forecasting, observations from 1984 to 1997

	NBSK	NBHK	NEWSPR	UMAGPAP	UFINEPAP	PMC	ACTPROD	DELIVER	INVENTOR	OECDIP	USPPI	FIM
NBSK	1.00											
NBHK	0.96	1.00										
NEWSPR	0.71	0.66	1.00									
UMAGPAP	0.65	0.62	0.97	1.00								
UFINEPAP	0.91	0.88	0.83	0.81	1.00							
PMC	0.18	0.21	0.49	0.60	0.38	1.00						
ACTPROD	0.32	0.39	0.42	0.47	0.44	0.77	1.00					
DELIVER	0.09	0.15	0.29	0.34	0.25	0.65	0.68	1.00				
INVENTOR	-0.28	-0.33	0.09	0.22	-0.10	0.50	0.14	-0.02	1.00			
OECDIP	0.46	0.45	0.71	0.77	0.62	0.90	0.73	0.62	0.38	1.00		
USPPI	0.29	0.28	0.56	0.66	0.46	0.92	0.69	0.58	0.56	0.95	1.00	
FIM	-0.72	-0.68	-0.85	-0.78	-0.75	-0.26	-0.26	-0.17	0.26	-0.50	-0.29	1.00

2.2 Methods Used in Forecasting and Analysis

This section will shortly describe the main methods used here in forecasting from and analysing time series. These are OLS (ordinary least squares) linear regression, error-correction and co-integration. Complete understanding of all the methods is not required for understanding the basic results of the forecasting models in later chapters, but is of good help. The basics covered next, however, are essential.

2.2.1 The Basics of Time Series Forecasting

The main idea behind time series forecasting is that the variable being forecast is affected by the state of its own and/or some other variables' past, e.g., NBSK pulp price is affected by NORSCAN market pulp inventory level last period. By knowing the level of inventory, it is possible to say something about what the pulp price might be. Also, as inventory levels do not double or halve overnight, also the previous inventory levels probably have some forecasting value.

As in this study, there are many forecasting variables, not just one. Let's say all affecting variables are accounted for in the model. Despite this, there is (almost) always a random component present, e.g., a fire might destroy a major pulp mill and thus capacity would be lower than expected. These random events are called white noise, and can not be forecast. Thus, the white noise causes forecasting errors.

Since decisions are, more or less, based on the forecasts, a criterion for a good forecast is needed. If there is an error, there will also be a cost to the decision maker. Generally, the larger the error, the larger the cost will be. A good forecast would, therefore, minimise this expected cost. The cost may be related to the error (*e*) in numerous ways. This cost function could be, for example,

$$C(e) = \begin{cases} 70e & \text{if } e > 0 \\ 30(-e) & \text{if } e < 0 \\ 0 & \text{if } e = 0 \end{cases} \tag{2-1}$$

It is easy to imagine situations where the cost of the error e would be linear and greater on the upper side of the forecast than on the lower side, e.g., production of goods selling for $1 and costing $0.70 to make, while forecasting demand. But often it is difficult to determine the true cost function. The usual approximation is the quadratic function

$$C(e) = e^2 \tag{2-2}$$

which simply determines the cost of an error as the error squared. The obvious problem with this choice for *C*(*e*) is that it is a symmetric function, whereas actual cost functions are often nonsymmetric. However, it is tractable, tidy and easy to use as, among other things, the best forecast for period t is the conditional mean of the variable's value at period t. (Granger 1980, pp. 13-15, Granger and Newbold 1986, pp. 121-127, Granger and Watson 1984, pp. 994-995)

Usually, the most important affecting variables are known or the best ones available chosen. However, the parameters of the model need to be estimated. This is mostly done with regression methods, the simplest of which, yet powerful, is the ordinary least squares (OLS) linear regression. This regression method uses the cost function in (2-2), i.e., it chooses parameter values so that the variance of the forecast errors is as small as possible. By minimising the variance, all other errors but white noise should be filtered out - assuming the model is perfect.

Example. A simple linear regression model for forecasting pulp price (P) change with inventory level (I) change last period is presented in equation 2-3:

$$\Delta P_t = \alpha + \beta \Delta I_{t-1} + \varepsilon_t \tag{2-3}$$

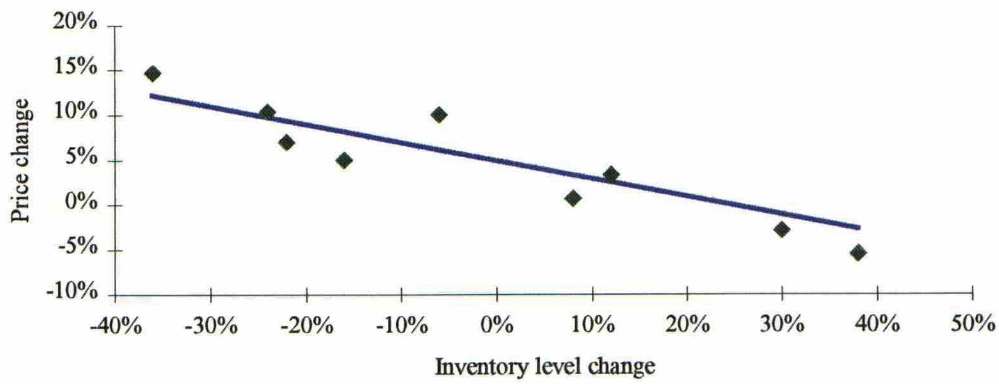
For the parameters α and β, values that minimise the sum of ε_t^2 and thus also the variance of ε, the error terms, are chosen by the method. The values might be, for example,

$$\alpha = 0.05$$

$$\beta = -0.2$$

indicating that there is probably an upward trend in pulp price (if inventories are stable, price change is +5%), and that rising inventories last period possibly mean falling pulp prices this period. Figure 2-8 shows one data set leading to regression coefficients presented above (with $C(e)=e^2$). In the figure, error terms equal the vertical distance between the actual values, i.e. the dots, and the regression values, i.e. the line.

Figure 2-8: Example of linear regression



One of the assumptions behind linear regression is normality. However, non-normal data must often be used. If changes in variables are entered into a linear regression and the variables have no upward or downward trend (e.g. as real price and de-trended inventory data), the changes are probably loglinear, as the negative percentage change is limited to -100%, but there is no upper limit. Thus logarithmic changes of the variables should be used, and then the forecast returned from logarithmic change to real value. This issue will be explained more thoroughly in chapter *3.2.1 Data Manipulation*, p. 30.

2.2.2 Co-integration and Error-Correction

The concepts of co-integration and error-correction are fairly recent advances in econometric modelling. According to Banerjee *et al.* (1993, p. 136),

> The concept of co-integration is a powerful one because it allows us to describe the existence of an equilibrium, or stationary, relationship among two or more time-series, each of which is individually non-stationary. That is, while the component time-series may have moments such as means, variances, and covariances varying with time, some linear combination of these series, which defines the equilibrium relationship, has time-invariant properties.

Typically, in economic applications co-integration among variables individually integrated of order one is looked for. The series y_t below is said to be integrated of order one, denoted $I(1)$, because taking the first difference of the series produces a stationary process, i.e., a series integrated of order zero, denoted $I(0)$ (Greene 1993, p. 559).

$$y_t = \mu + y_{t-1} + \varepsilon_t \tag{2-4}$$

The series in (2-4) is a common random walk with drift μ, and its first difference is

$$\Delta y_t = y_t - y_{t-1} = \mu + \varepsilon_t \tag{2-5}$$

Banerjee *et al.* (1993, p. 136-137) give a good informal definition of an integrated series. A series is integrated if it accumulates some past effects; it is non-stationary because its future path depends upon all past influences, and is not tied to some mean to which it must eventually return. Based on this, y_t in (2-4) is apparently integrated as its value is based on the previous values of itself. On the other hand, Δy_t in (2-5) is not integrated as its value is constant, μ plus some error term ε_t.

However, a linear combination of i series integrated of order d_i, $d_i>0 \ \forall \ i$, may be integrated of order smaller than $min(d_i)$, if some of the series are co-integrated. Consider the following construction (taken from Engle and Granger 1991, p. 6)[4]:

$$\begin{aligned} x_t &= AW_t + u_t \\ y_t &= W_t + v_t \end{aligned} \tag{2-6}$$

where W_t is $I(1)$ and u_t and v_t are both $I(0)$ with zero means. Then x_t and y_t are both $I(1)$ but their linear combination z_t, in the special case below, is $I(0)$ as the variable W_t drops out:

$$z_t = x_t - Ay_t = AW_t + u_t - A(W_t + v_t) = u_t - Av_t \tag{2-7}$$

Usually, for regression models, time series are differentiated to $I(0)$ to avoid "spurious regression". This term is used by Granger and Newbold (1986, p. 205) to describe regressions of an apparently high degree of goodness of fit, as measured by the coefficient of multiple correlation R^2 or the adjusted R^2, but with extremely low values for the Durbin-Watson test statistic d. A low d value indicates that the time series measured is autocorrelated, i.e., it is not $I(0)$ but has a "memory" in that variation is not independent from one period to the next. As many economic data are $I(1)$, a common example of "spurious regression" is regressing levels instead of changes in levels.

4 Notation used by Engle and Granger was slightly adapted.

However, by differentiating, the information content of the levels of the variables is lost (Johansen and Juselius 1990, p. 170). The *Engle-Granger two-step procedure* (Banerjee *et al.* 1993, p. 157, Engle and Granger 1991, pp. 6-8) first regresses the levels of the co-integrating variables, and then forms an error-correcting model for differentiated variables, which includes the error terms of the first regression. If the coefficient of the error term from the first regression is significant and negative, the variables tend to return to their equilibrium state in the long run.

The following example is adapted and simplified from Granger (1986, pp. 215-217). Consider two series, x_t and y_t, which are both $I(1)$, and that there exists a constant A such that

$$z_t = \alpha + x_t - Ay_t \tag{2-8}$$

is $I(0)$ - i.e., z_t, the deviation or "error" from the long-run equilibrium state $x_t=Ay_t-\alpha$ is stationary. It should be noted that there exists only one unique A which satisfies these conditions, and that α is chosen so that the mean of z_t is zero. Now, these errors are accounted for when forming regressions of the differentiated variables:

$$\begin{aligned} \Delta x_t &= -\rho_1 z_{t-1} + \text{lagged}\left(\Delta x_t, \Delta y_t\right) + \varepsilon_{1t} \\ \Delta y_t &= -\rho_2 z_{t-1} + \text{lagged}\left(\Delta x_t, \Delta y_t\right) + \varepsilon_{2t} \end{aligned} \tag{2-9}$$

The coefficients ρ have a very intuitive interpretation. Assume ρ_1=0.5 and a shock moves the equation $x_t=Ay_t-\alpha$ out of equilibrium. If there are no further shocks, the upper equation in (2-9) would converge to equilibrium - the "error" would halve each of the following periods t. The lagged variables may be chosen freely.

2.2.3 Statistical Tests

The statistical tests used in testing the models and variables will be briefly explained below.

Student *t*-test

The *t*-distribution has essentially the same shape as normal distribution but has thicker tails (Greene 1993, p. 159). The *t*-distribution with infinite degrees of freedom is the same as normal distribution, and the degree of freedom is based on the number of observations in a regression. The size of the *t*-statistic tells how far from some benchmark the tested number is. In this study, it is used to test if the coefficients are far enough from zero to have a meaningful interpretation.

Chow test

The Chow test is used to test if there has been a structural change within the regression period. A structural change would mean that the results may no longer apply in later periods. The regression is estimated separately for two halves of the regression period, and the sums of squared errors from both are then used to calculate the statistic (see White 1993, pp. 178-179 or Greene 1993, pp. 211-212). If the two sums are very different in magnitude, it is interpreted as a sign of structural change.

Goldfeld-Quant test

The Goldfeld-Quant test compares the same sums of squared errors as the Chow test, but simply by dividing one with the other. The test is used to check if the model is heteroscedastic, i.e., if the variance of the error terms changes in the estimation period.

Augmented Dickey-Fuller and Phillips-Perron tests

The ADF and PP tests are for testing co-integration or unit roots in variables. The tests construct test statistics from the residuals of a co-integrating regression. The test for co-integration is actually a unit root test for the estimated regression residuals. The unit root test, then, is a test of whether a lagged level of a variable is significant as a regressor for the change in that variable; if so, a unit root is found to exist. The Phillips-Perron test differs from Augmented Dickey-Fuller test in that the PP test corrects for serial correlation with a non-parametric correction, while the ADF test uses several lags of the variable. (White 1993, pp. 157-159)

2.3 Software Used in Forecasting

The software used in this study was SHAZAM version 7.0, an econometrics and statistical analysis package available for several computer environments. While the use of this program requires some programming in the form of command scripts, it is very flexible and can produce output readable by most spreadsheet programs. The actual scripts used are not included in this study due to their length.

3 PRICE FORECASTING

3.1 Papers on Pulp and Paper Prices Forecasting

There are numerous forecasts of pulp and paper prices available from consulting companies, investment banks, etc. all over the world. However, these do not usually cover the methods and data used but only the forecasts. And, of course, these companies charge a considerable fee for their services.

There are few econometric studies concerning the Finnish pulp and paper industry exports, and these do not usually include price behaviour analysis. Also, it is difficult to find almost any recent studies (excluding the aforementioned commercial products) concerning specifically pulp and/or paper prices forecasting. Some of the recent work relating to the topic is discussed below.

One recent paper written in the Finnish Forest Research Institute attempting to forecast chemical sulphate pulp price is Toppinen, Laaksonen, and Hänninen (1996). They use the Johansen co-integration method, and find a long-run equilibrium to exist between pulp price and NORSCAN inventory for the research period 1980-1994. The study utilises only quarterly data of price and inventories, because other variables were not easily available.

The conducted Granger causality tests show that there exists a strong causality from pulp inventory to price when using up to four lags, but not from price to inventory. Thus, while inventories improve the one-step-ahead price forecast, feedback does not exist from price to inventory. Results from both Johansen's trace and maximum eigenvalue tests indicate co-integration between price and inventory with one lag, but not for any longer lag structure.

To summarise some of the main results of the paper, the authors find that moderate price changes can be well explained by changes in inventory level. On the other hand, their model is too crude for forecasting the cyclical turning points in pulp price. The absolute value of lagged co-integrating vector is estimated to be -0.33, which the authors interpret indicates that the adjustment to long-run equilibrium would take place in approximately three quarters of a year.

A recent paper written in the University of Umeå, Sweden, Brännlund and Löfgren (1995), deals with cyclical dumping and correlated business cycles in Canadian pulp and paper industry. They form an econometric model of supply and demand, and find that cyclical dumping, i.e., pricing exports cyclically while selling at a stable price in the home market, does exists in the Canadian pulp market, but not in the newsprint market. This dumping might add to the cyclical price behaviour of the world pulp market.

Baudin, Nadeau, and Westlund (1984) study the U.S. pulp and paper market and, more specifically, test two different adaptive estimation techniques when economic systems are believed to be structurally unstable over time. Their model of the U.S. pulp and paper market consists of five structural equations, and although their objective is to model demand, supply and imports, the model's variables may be useful in price forecasting, too. Paper and paperboard demand is measured as apparent consumption, being determined by general industrial activity, producers' stocks and a deflated price index for paper and paperboard products. The supply of paper and paperboard is considered to be primarily the demand fulfilment, but price in also included as a way to take profitability into consideration. For pulp, the production level of paper and paperboard determines demand. The remaining two equations model paper and pulp imports.

Baudin, Nadeau and Westlund find that adaptive estimation techniques are indeed able to improve forecasting accuracy. When comparing Kalman filtering and Carbone-Longini filtering, they find that the latter might be more robust against misspecifications, but otherwise the two are very competitive from a forecasting ability viewpoint.

Paper demand is also studied in a paper by Baudin and Lundberg (1985). Their results suggest that paper demand is strongly related to the development of general economic indicators. Also, they find that an hypothesis of paper demand reaching a saturation level in the future could hardly be justified by statistical analysis of historical data.

3.2 Data Manipulation and Preliminary Analysis

Before generating a model and running the actual statistical analysis, the data were manipulated in several ways to make them more feasible for reliable analysis. Also, the basic relationships among variables were studied, so that the actual process of deciding on a model would be easier.

3.2.1 Data Manipulation

All price data were first, if necessary, converted to U.S. dollars and then deflated with the U.S. Producer Price Index. The resulting series were all expressed in today's dollars, today being the date of the most recent pulp price data. Next, differenced series for all price data were calculated by taking natural logarithms of the ratios of the price and the price *j* periods earlier, as expressed in formula (3-1):

$$\Delta P_t^j = \ln\left(\frac{P_t}{P_{t-j}}\right) \tag{3-1}$$

Natural logarithms were used instead of "straight" percentual changes (e.g. in 3-1: $(P_t - P_{t-j})/P_{t-j})$ to obtain better normally distributed variables, as one of the assumptions behind the regression model used is normality. The distribution of percentual changes, especially in long intervals, is necessarily skewed to the right, as a change from \$500 to \$1000 is +100% but from \$1000 to \$500 only -50%. The respective natural logarithmic changes, however, are +69.3% and -69.3%. The percentual change distribution is lognormal.

While the model delivers an unbiased forecast for the natural logarithmic change of the forecast variable, the conversion to absolute price level is not as straightforward as using equation (3-2):

$$price_t = price_{t-j} \times e^{change} \tag{3-2}$$

The above equation would give too small a value, since the price distribution is log-normal and skewed to the right. The formula used in this study is based on the properties of lognormal distribution. The expected value of *price* is calculated as follows (Granger 1980, p. 114):

$$price_t = price_{t-j} \times e^{change + \frac{\mathrm{var}(change)}{2}} \tag{3-3}$$

The upward trends in the data on pulp actual production, inventories, and deliveries, were removed by dividing the values by respective potential manufacturing capacity. This removed the obvious rise in, e.g., inventory levels caused by the growth in production. Also, moving average values for these variables were calculated by adding n months' values together and then dividing by respective n months' PMC. For forecasting purposes, these averages contain only realised observations, e.g. in the end of March a three month moving average would be the average of January, February, and March observations. In all figures, the moving averages are also presented this way.

Haavisto, Tahvanainen, and Teräs all separately suggested the use of a new variable based on the estimated three-week PMC and inventory level. The three-week PMC figure is seen as a turning point for pulp price when inventory level crosses it. More precisely, when inventory level is above the three-week PMC, prices tend to fall and when inventory level is below the three-week PMC, prices tend to rise. The new variable would be calculated by first subtracting 75% of the month's PMC from the inventory level, and then dividing the result by 75% PMC, as in formula (3-4):

$$\frac{\text{Inventory level} - 75\%\ \text{PMC}}{75\%\ \text{PMC}} \tag{3-4}$$

The dividing would be done again to remove a trend, which in this case would have been a trend of increasing absolute deviations from mean due to the increase in absolute values of variables.

Another new variable, deliveries divided by inventory level, was also suggested. This variable is used by some consulting agencies to integrate both supply and demand into a single forecasting factor. No trend-removal was necessary for this variable, as both deliveries and inventory level are thought to have the same upward trend.

However, as in creating the forecasting models all these variables are tested for forecasting power simultaneously, there is no need for these additional variables. The former is equivalent to (Inventory level / 75% PMC) - 1, and since the dividing with 75% is unnecessary (the coefficient will compensate for that) and the constant of the equation will compensate for "-1", the already included Inventory level / PMC variable is as good as the suggested new variable. The latter was found to be insignificant in forecasting when the other inventories and deliveries-based variables were included.

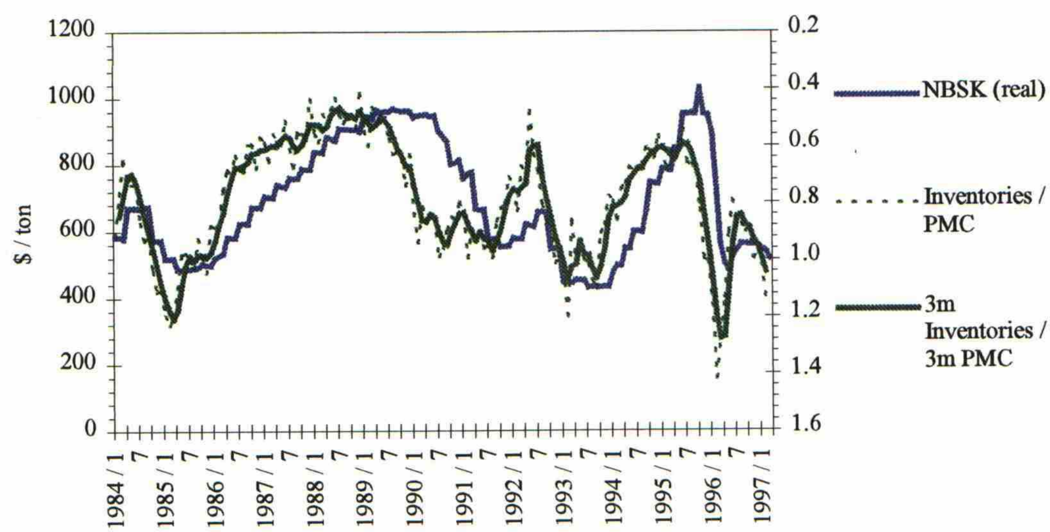
Differenced series for most of the above variables were calculated in the same manner as for price data.

3.2.2 Pulp Preliminary Analysis

For preliminary analysis, the relationships between pulp price and other variables were carefully studied. Both levels and changes were used to find out if the variables would be useful in forecasting as co-integrated or differenced variables, or both.

The first variable studied was inventory level, as it is a widely known fact that inventory level is a very important factor in pulp price forecasting. As shown in figure 3-1, there seems to be a high correlation between price level and inventory level. When inventory level goes down (note that the inventory level scale has been inverted to emphasise correlation), price goes up, and vice versa. It can also be noted that the inventory level changes seem to lead the price behaviour by a few months.

Figure 3-1: NBSK pulp real price and one and three month inventory level / PMC (inverted scale) 1984-1997

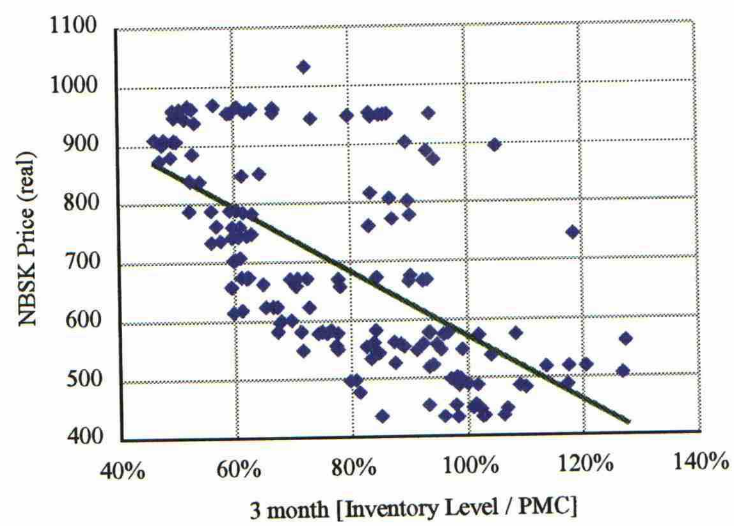


The three month figure (continuous line) is a moving average, which is designed to filter out most of the "random behaviour" or "false signals" of the one month figure (dotted line). Although this filtering does have a cost in the form of not being as quick in reacting to changes in inventory level, it has the valuable advantage of being more reliable in forecasting.

It seems that the two variables above are co-integrated. This can be seen again in figure 3-2, where NBSK pulp real price and inventory level / PMC are shown in a scatter diagram. The regression line describes the co-integration equilibrium, as explained in section *2.2.2 Co-integration and Error-Correction*, pp. 23-25. The equilibrium prices could be described as the average prices of each inventory level[5]. Even though there are quite large deviations from the estimated equilibrium, correlation and co-integration seem to exist.

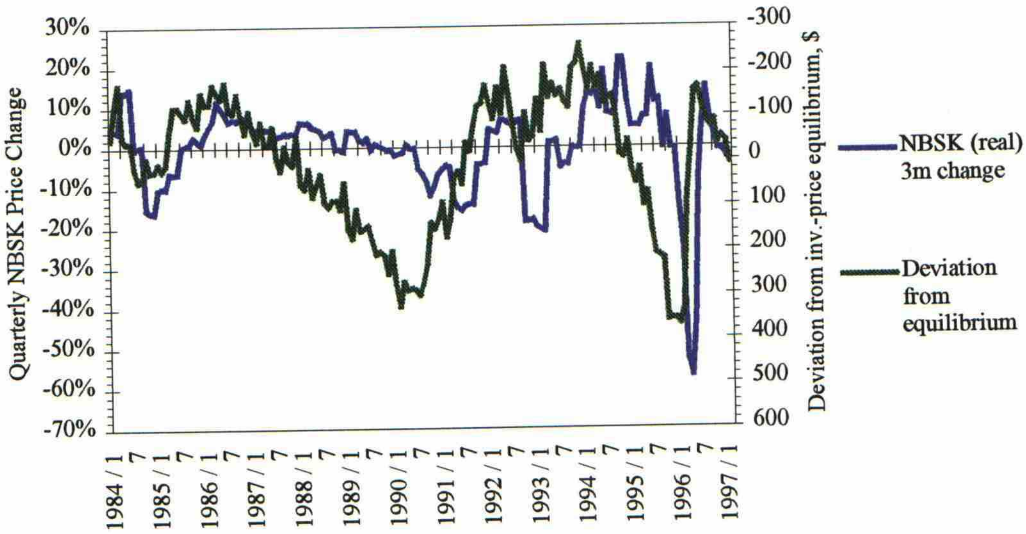
The forecasting ability of the deviations from equilibrium can be evaluated by looking at the deviations and price change in figure 3-3 (note the inverted scale for deviations). Despite some exceptions such as late 1992-1993, the forecasting ability of the deviation from equilibrium is evident. Difficulties arise, however, from the facts that the speed with which pulp price has reacted to disequilibrium condition has grown, and recently the changes in price have been much faster and greater than before.

Figure 3-2: NBSK pulp real price and three months' aggregate inventory level as percentage of potential manufacturing capacity 1984-1997 with an OLS regression line



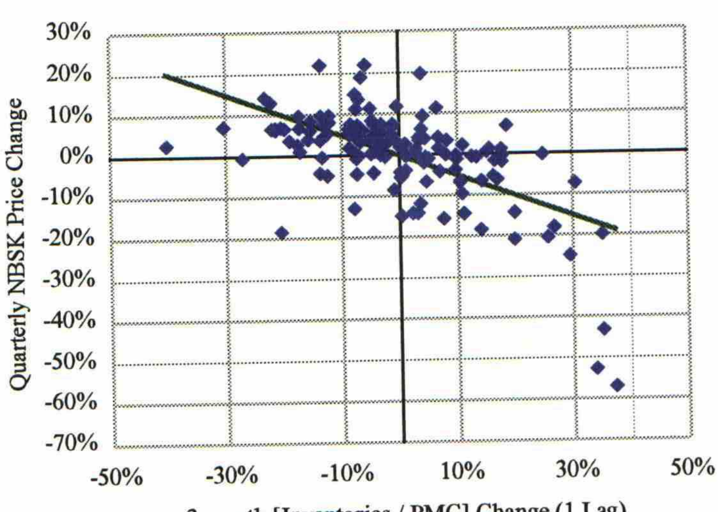
5 This description is not quite accurate, but gives a simplified view of the equilibrium.

Figure 3-3: Quarterly NBSK pulp real price change and deviation of price from estimated inventory level equilibrium price (inverted scale) 1984-1997



Also it seems that changes in inventory level predict changes in pulp price. This may be analysed more thoroughly by drawing again a scatter diagram of the changes, and lagging the predictor. In the following scatter diagrams, a lag length of one quarter, i.e. three months, was used.

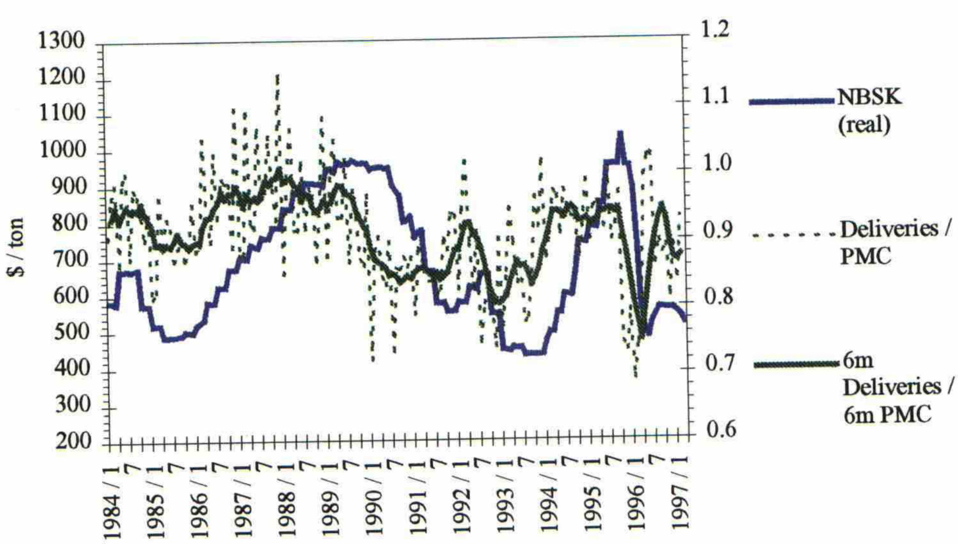
Figure 3-4: Quarterly NBSK pulp price change and three-month inventory level / PMC change 1984-1997 with an OLS regression line



In figure 3-4, three month changes are used for both variables, because two thirds of the one-month pulp price changes for the years prior to 1994 are so close to zero. In the figure, the observation made from figure 3-1 is at least partially confirmed: there seems to exist a negative correlation between pulp price and inventory level, when inventory level is lagged. While the upper right and lower left quarters of the figure clearly contain a lot less than one half of the observations, deviations from the regression line are relatively large and, thus, predictability may be low. The three lower-right observations are from the beginning of 1996, when pulp price crashed.

It was assumed that the correlation coefficient (and thus the slope of the regression line in figure 3-4) would be negative, as rising inventory levels would cause pulp makers to lower prices and vice versa. This assumption was correct.

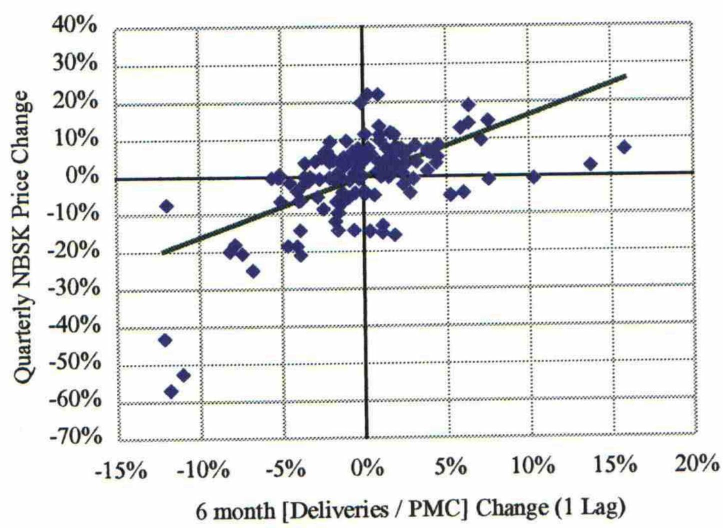
Figure 3-5: NBSK pulp real price and one and six month deliveries / PMC 1984-1997



Next, pulp deliveries were analysed. In a similar fashion as above, two figures were drawn. In the first, figure 3-5, co-integration seems again to be present, even though the relationship between deliveries and price may be a bit weaker than between inventory level and price. Also it must be noted that the one-month deliveries statistics is very volatile and thus a 6-month moving average was chosen for a more stable indicator of the general development in deliveries.

In the scatter diagram (figure 3-6), correlation can again be found. The link between inventory level, deliveries, and actual production (change in inventory level equals the difference between actual production and deliveries) can be observed by comparing figures 3-4 and 3-6: they seem to be very close to being mirror images of each other. However, as actual production is rather slow to react to changes in deliveries, the change in inventory level may still be large even if deliveries stay the same.

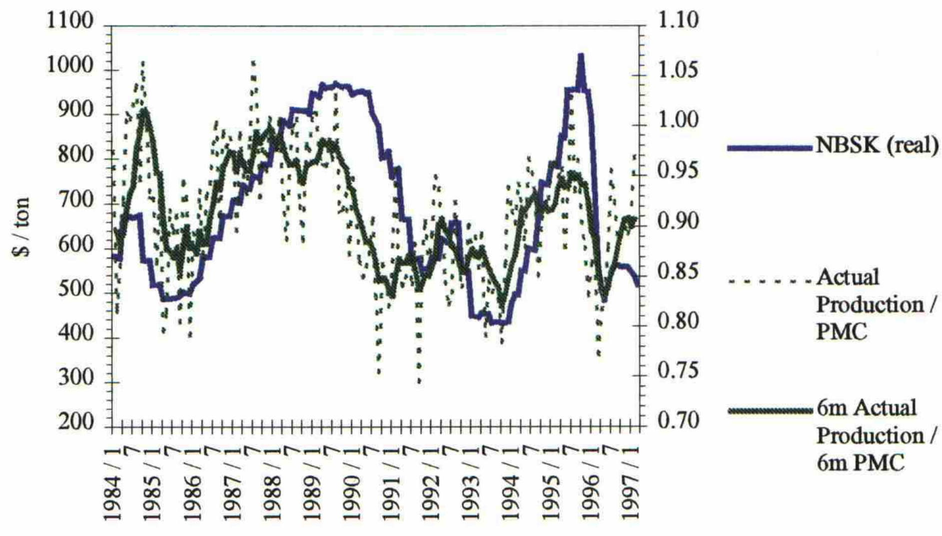
Figure 3-6: Quarterly NBSK pulp price change and six-month deliveries / PMC change 1984-1997 with an OLS regression line



It was again assumed before analysis that the slope of the line in the figure above would be positive, because rising deliveries would mean greater demand and thus give pulp makers a chance to sell at higher prices.

For actual production, correlation seems again to exist (figure 3-7) but it is more difficult to determine if actual production change leads pulp price change or vice versa, as sometimes actual production changes first, sometimes pulp price. It can be observed that the one month actual production (dotted line) is very volatile and thus rather useless as a predictor.

Figure 3-7: NBSK pulp real price and one and six month actual production / PMC 1984-1997



It was assumed that production cuts would decrease supply and thus enable pulp makers to increase prices. However, in figure 3-8 the slope of the regression line is positive indicating that a rise in production leads to a rise in price. This unexpected result implies that the relationship between the two variables works the other way around: producers follow pulp price changes when deciding production levels, as was to some degree suggested by figure 3-7, too.

In conclusion, actual production does not seem to be a good predictor of pulp price, at least in the short run.

As expected, uncoated fine paper price tracks pulp price very closely (see figure 3-9). Uncoated fine paper was selected for pulp price forecasting, because it contains the largest proportion of chemical pulp of the paper grades studied (see table 1-4, p. 8). Because the difference between pulp and uncoated fine paper prices is relatively stable, turning point forecasting ability in either direction seems poor. There is probably some forecasting ability of price change, however, as the cycles are so long.

Figure 3-8: Quarterly NBSK pulp price change and six-month actual production / PMC change 1984-1997 with an OLS regression line

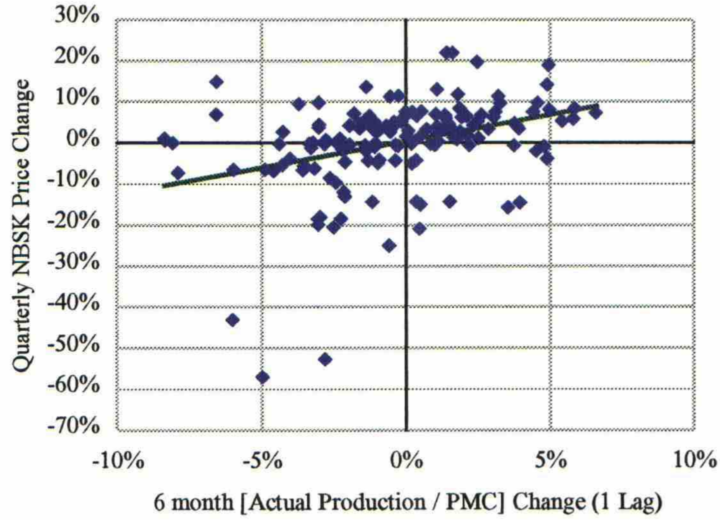
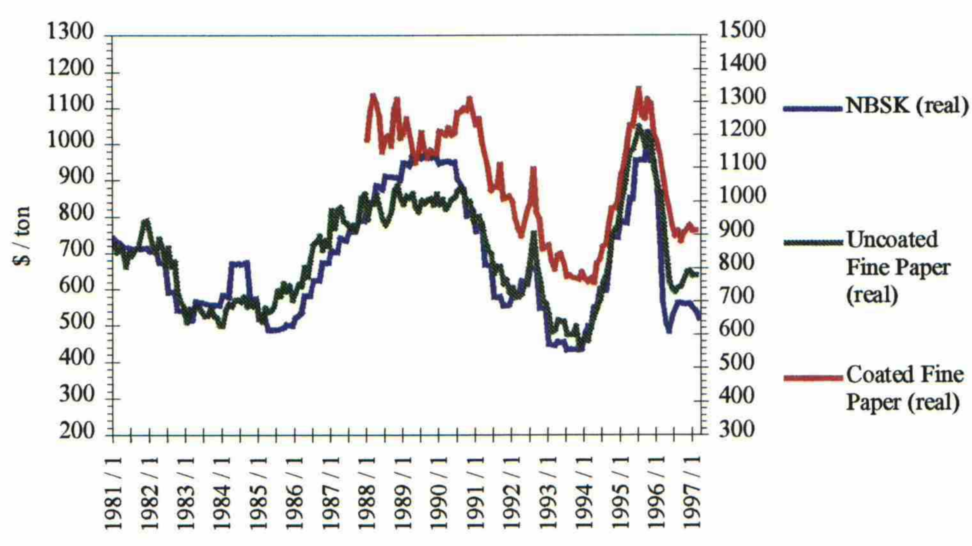
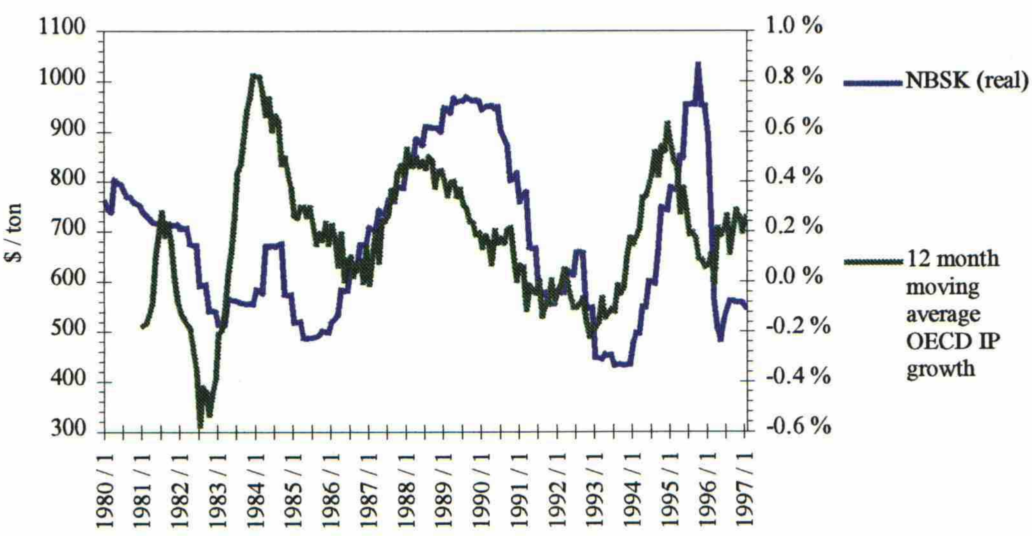


Figure 3-9: NBSK pulp real price and uncoated fine paper real export price 1984-1997



Long-term paper demand is largely affected by GDP and industrial production development. Thus, OECD industrial production growth should imply rising paper and pulp demand and higher prices. As is seen in figure 3-10, industrial production and pulp price do have more or less the same cycles, but the magnitudes of changes in these variables are not very closely related. However, even though industrial production is a much less accurate predictor than other variables presented above, it has (except in 1985-86) been rather good at forecasting pulp price turning points. Thus, it may be useful especially when constructing longer term forecasts. Some of this ability is, though, lost in the filtering process, but even a six month moving average is too volatile to give reliable forecasts.

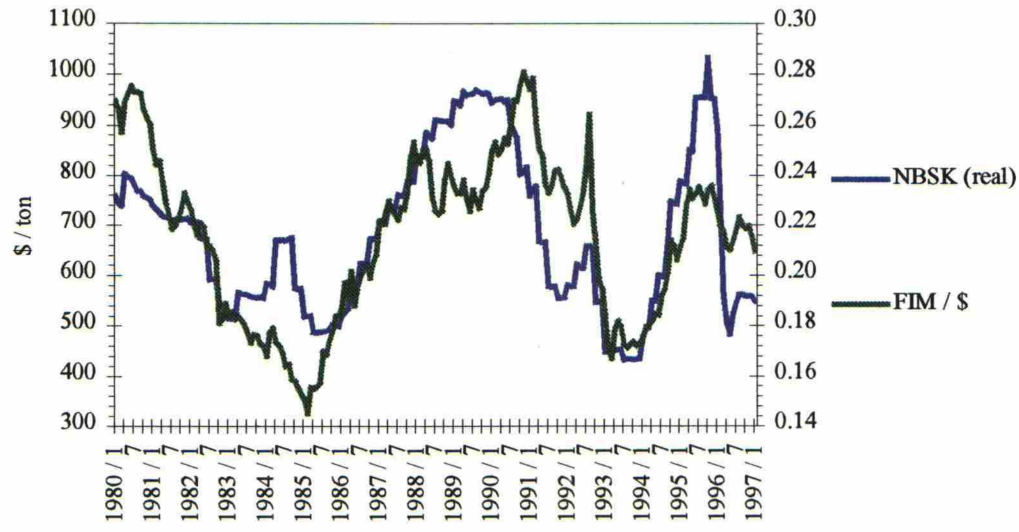
Figure 3-10: NBSK pulp real price and twelve month moving average OECD industrial production growth 1980:I-1997



A very interesting relationship was found between the exchange rate of Finnish Markka and U.S. Dollar and pulp real price. As FIM / $ exchange rate cannot, at least not very much, affect the world market pulp price in Figure 3-11, either U.S. Dollar's value is reflected in the price because North America is such a large consumer of pulp, or FIM / $ exchange rate (i.e., FIM value) is affected by pulp price.

The latter is probably much closer to the truth, as the FIM value of pulp has been much more stable than the U.S. Dollar value.

Figure 3-11: NBSK pulp real price and FIM / $ exchange rate 1980:I-1997



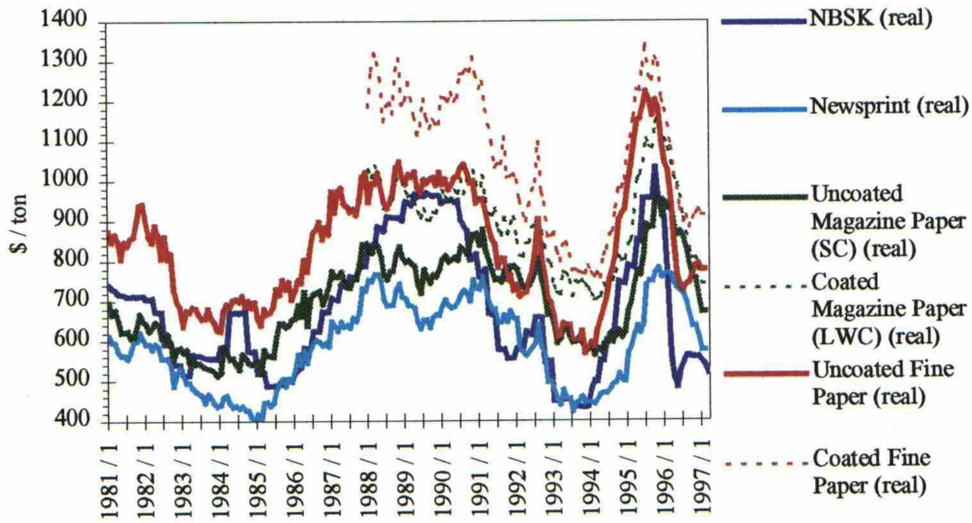
With the recent ERM and EMU development in mind, this finding is very probably not useful for forecasting purposes and thus not included in any of the models.

3.2.3 Paper Grades Preliminary Analysis

As described in Table 1-4 on page 8, the five paper grades of the study have different constituents. The fact that fine papers are made mostly of chemical pulp and the other grades mostly of mechanical pulp suggests that the former group should correlate better with NBSK than the latter. This can be seen to be true by looking at figure 3-12, where the price histories of all grades and NBSK pulp are plotted.

Furthermore, the strong relations between NBSK and fine papers as well as between newsprint and magazine papers are obvious. It also seems that fine paper prices are more sensitive to changes in the markets, because when NBSK pulp price is high, fine papers have been $100 to $300 more expensive than magazine papers, while magazine papers may be at the same or even higher (April to September, 1996) prices when NBSK pulp is cheap.

Figure 3-12: NBSK and uncoated paper grades real prices 1981 - 1997, coated grades 1988 - 1997 (sources: PaperInfo Oy and FFIF)



Data of coated paper grades were, unfortunately, not available prior to 1988. As the coated grade price changes are very closely linked to uncoated grade price changes, and there were no data available for forecasting the coating price's changes, the coated grades were not analysed separately. Instead, the difference between coated and uncoated grades' prices was studied. It seems that the difference between coated and uncoated paper price has become smaller for both magazine and fine papers, but since both differences fluctuate rather wildly and there probably have been changes in coatings and their prices, it is difficult to say whether this phenomenon is just temporary or permanent. Nevertheless, the average price premium for coating has, on average, been around $150 for both grades for the last three years.

Figure 3-13: Uncoated fine paper real price change in six months and the deviation of uncoated fine paper real price from the calculated equilibrium price based on NBSK real price (inverted scale) 1981-1997

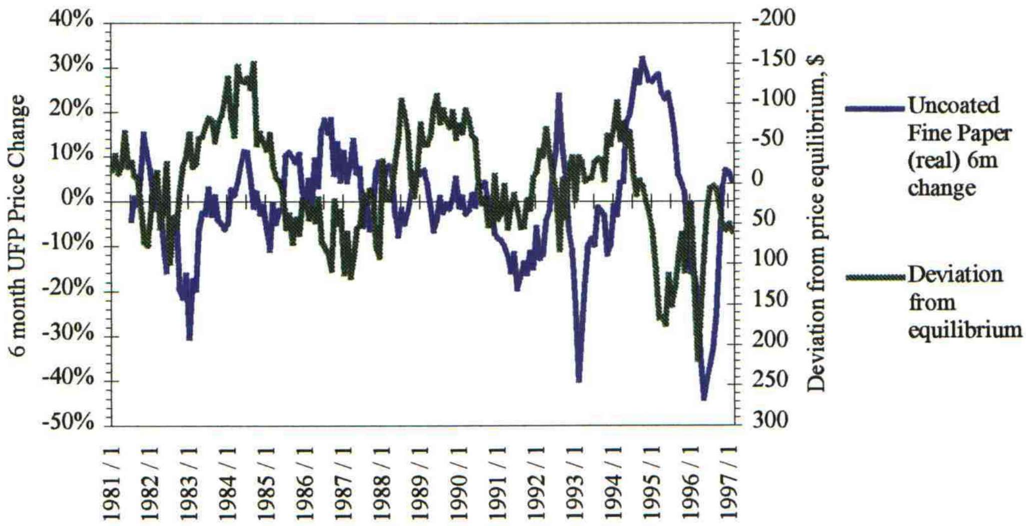
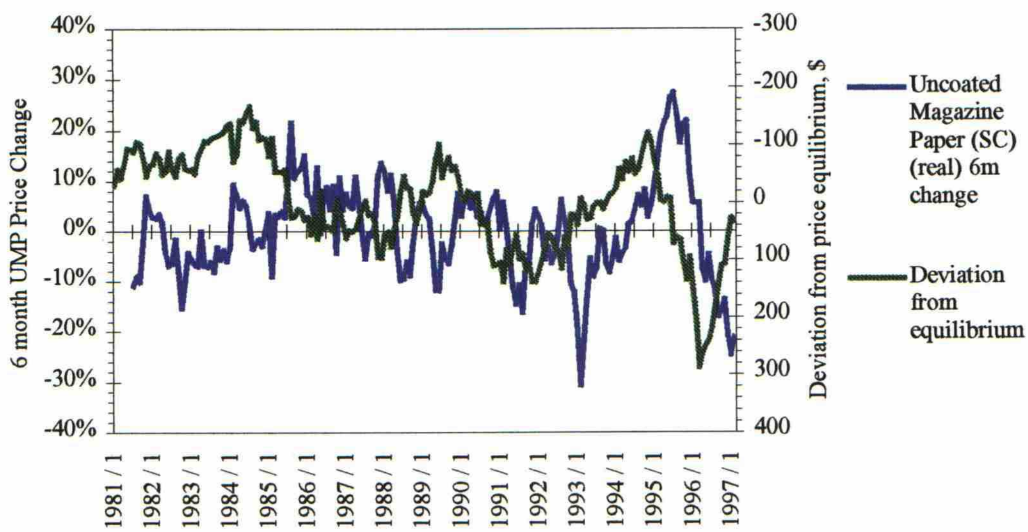


Figure 3-14: Uncoated magazine paper (SC) real price change in six months and the deviation of uncoated magazine paper (SC) real price from the calculated equilibrium price based on NBSK real price (inverted scale) 1981-1997



The co-integration of all series in figure 3-12 seems probable, as prices of substitutes (paper grades) and primary raw material and the end products (pulp and paper) can not diverge from each other too much in the long run. The mechanical pulp-based papers should have weaker co-integration with NBSK pulp than fine papers, which are based on chemical (NBHK and NBSK) pulp. Uncoated fine paper, in figure 3-13, and uncoated magazine paper, in figure 3-14, however, seem to fluctuate around their equilibrium levels approximately equally much.

Both paper grades' price changes mostly move to the same direction as the deviation from equilibrium level suggests. However, the relationships are far less clear than with pulp. This may be due to fluctuating 6 month changes in paper prices.

3.2.4 Variables Used in Forecasting and Their Correlation

The basic statistics of selected calculated variables are presented in table 3-3. All variables used as predictors later in forecasting models and three and twelve month changes in predicted variables are shown. It is interesting to note that the variance of NBHK changes is greater than NBSK's, as are the minimum and maximum changes. Also of interest are the variances of the last six co-integration-based variables. The largest are the NBSK deviations from inventories or deliveries-based equilibrium prices, while uncoated magazine paper seldom moves far from newsprint-based equilibrium price. The distribution of NBSK deviations from NBHK-based equilibrium looks strongly skewed to the right when examining the minimum ($-94) and maximum ($+219); it seems that while NBSK may for short periods trade for much higher prices than NBHK, NBHK usually forms a price-stop level at the lower end.

Table 3-1: Basic statistics of selected calculated variables; variable name, number of observations, mean, standard deviation, variance, and minimum and maximum values. In names, "r" in the end denotes real value (nominal value deflated by US producer price index). The bottom six variables are based on co-integration relationships; e.g. NBSKr - (inv/PMC eq.) *means the deviation of NBSK real price of the equilibrium NBSK real price based on current NBSK inventories / potential manufacturing capacity level.*

	NAME	N	MEAN	ST. DEV	VAR.	MIN.	MAX.
3 mo. log change in NBSKr	**M3NBSKR**	206	-0.0045	0.1016	0.0103	-0.5688	0.2209
3 mo. log change in NBHKr	**M3NBHKR**	206	-0.0056	0.1278	0.0163	-0.6634	0.2961
3 mo. log change in UFPr	**M3UFPR**	194	-0.0015	0.0824	0.0068	-0.2956	0.1851
3 mo. log change in UMPr	**M3UMAGR**	194	0.0001	0.0629	0.0040	-0.1923	0.1733
3 mo. log change in NPr	**M3NEWSR**	194	-0.0004	0.0689	0.0048	-0.2553	0.2090
12 mo. log change in NBSKr	**M12NBSKR**	206	-0.0203	0.2520	0.0635	-0.6122	0.5450
12 mo. log change in NBHKr	**M12NBHKR**	206	-0.0228	0.2988	0.0893	-0.7770	0.7589
12 mo. log change in UFPr	**M12UFPR**	194	-0.0063	0.2061	0.0425	-0.5188	0.5745
12 mo. log change in UMPr	**M12UMAGR**	194	0.0131	0.1406	0.0198	-0.3398	0.4499
12 mo. log change in NPr	**M12NEWSR**	194	0.0081	0.1685	0.0284	-0.3704	0.4403
3 mo. log ch. in inv./PMC	**M3INVENP**	158	0.0057	0.1668	0.0278	-0.5591	0.5299
3 mo. log ch. in deliv./PMC	**M3DELIVP**	158	-0.0013	0.0922	0.0085	-0.2294	0.3665
12 mo. log ch. in OECD IP	**M12OIP**	206	0.0200	0.0315	0.0010	-0.0689	0.0991
NBSKr - (inv./PMC eq.)	**INVRESID**	158	0.00	129.39	16742	-259.61	365.56
NBSKr - (del./PMC eq.)	**DELRESID**	158	0.00	150.91	22773	-263.27	355.56
NBSKr - (NBHKr eq.)	**HKRESID**	206	0.00	44.31	1963	-94.09	218.94
NBSKr - (UFPr eq.)	**UFPRESID**	194	0.00	68.68	4717	-228.29	158.81
UFPr - (UMPr eq.)	**PUMPRES**	194	0.00	95.19	9061	-282.34	250.14
UMPr - (NPr eq.)	**PNEWSRES**	194	0.00	34.04	1159	-96.96	76.05

The correlation matrix shown in table 3-4 presents the correlation coefficients for the same variables as were in the previous table. The highest correlation is between uncoated magazine paper and newsprint real price changes and NBSK and NBHK real price changes. High values are also found between uncoated fine paper and NBSK and NBHK real price changes, the deviation of uncoated magazine paper from newsprint real price-based equilibrium and uncoated fine paper price change, and the deviations of NBSK price from inventories and deliveries-based equilibria.

Table 3-2: Correlation matrix of selected calculated variables, observations from 1984 to 1997. Values greater than 0.8 in absolute value bolded

	M3NBSKR	M3NBHKR	M3UFPR	M3UMAGR	M3NEWSR	M12NBSKR	M12NBHKR	M12UFPR	M12UMAGR	M12NEWSR
M3NBSKR	1.00									
M3NBHKR	**0.89**	1.00								
M3UFPR	0.68	0.61	1.00							
M3UMAGR	0.32	0.29	0.60	1.00						
M3NEWSR	0.33	0.29	0.61	**0.89**	1.00					
M12NBSKR	0.54	0.45	0.54	0.46	0.45	1.00				
M12NBHKR	0.56	0.54	0.55	0.45	0.40	**0.93**	1.00			
M12UFPR	0.41	0.35	0.59	0.60	0.59	**0.90**	**0.84**	1.00		
M12UMAGR	0.11	0.10	0.20	0.62	0.60	0.54	0.49	0.69	1.00	
M12NEWSR	0.18	0.18	0.26	0.58	0.65	0.55	0.48	0.69	**0.94**	1.00
M3INVENP	-0.19	-0.17	-0.07	-0.04	-0.08	0.12	0.07	0.11	0.06	-0.04
M3DELIVP	-0.29	-0.30	-0.21	-0.12	-0.05	-0.18	-0.19	-0.13	-0.10	-0.04
M12OIP	0.35	0.28	0.36	0.22	0.21	0.47	0.40	0.36	0.17	0.21
INVRESID	-0.11	-0.16	-0.08	0.14	0.11	0.26	0.17	0.28	0.39	0.32
DELRESID	0.20	0.13	0.14	0.24	0.21	0.53	0.45	0.45	0.42	0.40
HKRESID	-0.21	-0.35	-0.16	-0.04	0.02	-0.14	-0.38	-0.09	0.06	0.10
UFPRESID	0.27	0.19	-0.03	-0.18	-0.25	0.21	0.15	-0.06	-0.25	-0.32
PUMPRES	0.37	0.27	0.53	0.43	0.44	0.79	0.71	**0.85**	0.48	0.49
PNEWSRES	-0.18	-0.22	-0.13	0.12	-0.04	-0.16	-0.14	-0.05	0.14	-0.05

	M3INVENP	M3DELIVP	M12OIP	INVRESID	DELRESID	HKRESID	UFPRESID	PUMPRES	PNEWSRES
M3INVENP	1.00								
M3DELIVP	-0.35	1.00							
M12OIP	-0.07	0.02	1.00						
INVRESID	0.55	-0.26	0.12	1.00					
DELRESID	0.30	-0.25	0.28	**0.87**	1.00				
HKRESID	0.02	0.11	0.12	0.44	0.31	1.00			
UFPRESID	0.16	-0.19	0.39	0.39	0.48	0.26	1.00		
PUMPRES	0.24	-0.18	0.49	0.55	0.71	0.13	0.22	1.00	
PNEWSRES	0.10	-0.06	-0.52	-0.16	-0.33	-0.31	-0.39	-0.33	1.00

3.3 Forecasting Models and Results

When constructing the forecasting models, the first issue studied was the co-integration relationships in the data. Next, first phase models were created based on preliminary analysis and the observed or presumed co-integration relationships. The models were used in SHAZAM runs and then changed according to results, if one or more of the variables did not seem to fit in the models. Also, new variables were entered in the models. The method was a mixture of choosing variables according to presumed relationships between them and their statistical significance in models.

One problem in choosing the variables in each model was that some variables' statistical significance was quite unstable between models, for example a variable may have been highly statistically significant in 2, 3, 5 and 6 month models but not significant in 1 and 4 month models. However, it did not seem sensible to choose variables entirely based on statistical significance nor separately for each model. As a solution, two models for pulp and for each of the three paper grades, a short term model for periods 6 month or less long and a long term model for periods longer than 6 month, were constructed.

All models were estimated using seven years of price change data (84 observations). However, as at best a twelve month change of a variable was lagged 25 months (OECD Industrial Production in 24 month models), data from 10 years and 1 month (February, 1987 to February, 1997) were used. Even though 84 is not the maximum number of observations (the maximum is 131 to 134 depending on model), it was chosen because including the additional observations seemed to weaken the models. The longer period models, when tried, were more heteroscedastic and less stable and had smaller adjusted coefficients of determination. In conclusion, the earlier data do not represent the current conditions as well as present data. However, shorter periods than seven years have too small amount of observations; the results become more dependable on at which point the models are estimated.

In the following sub-chapters, the co-integration relationships are explained first, pulp models next, and paper models last. In a way the models are presented in an ease-of-forecasting order: the pulp short term models seem to be the most effective ones, and as the paper models are presented in an order where the ones which use the greatest proportion of NBSK and NBHK pulp as ingredients come first, the forecasting ability weakens towards the last model due to most forecasting variables being NBSK pulp based. Many variables and issues are first encountered with the pulp short term model and thus illustrated in that sub-chapter, later sub-chapters being briefer.

3.3.1 Co-Integration Relationships

As was noted in preliminary analysis, many of the study's variables seem co-integrated, as they track each other's paths quite well. However, statistical tests show that co-integration does not necessarily exist. See chapter *2.2.3 Statistical Tests*

for an explanation of the statistical tests.

Table 3-3: Augmented Dickey-Fuller and Phillips-Perron test probability p-values for co-integration of selected variables (p-values below 10% level bolded)

	Augmented Dickey-Fuller Test *p*-value	Phillips-Perron Test *p*-value
NBSK price and NBHK price	**0.076**	**0.089**
NBSK price and NBSK Inventory level	0.117	0.151
NBSK price and NBSK Deliveries	0.123	0.275
NBSK and Uncoated Fine Paper prices	0.119	**0.068**
Uncoated Fine Paper and Uncoated Mag. Paper prices	**0.079**	0.172
Uncoated Magazine Paper and Newsprint prices	0.181	0.102
NBSK price and FIM/USD	**0.094**	0.159

The results are not easily interpreted. The null hypothesis that variables are not co-integrated can be rejected with 90% certainty only for NBSK and NBHK pulps by both tests. NBSK pulp and uncoated fine paper, uncoated fine paper and uncoated magazine paper, and NBSK pulp and FIM/USD exchange rate are seen co-integrated with less than 10% chance of error by one of the two tests. The probability of falsely detecting co-integration between the other variable pairs is greater than 10%, although mostly less than 20%, by both tests.

It is striking how the two tests' results differ from each other. The main difference of the tests is in the way of handling serial correlation in the variables, so the high serial correlation of most of the study's variables may cause these differences.

3.3.2 Pulp Short Term

Pulp short term models forecast NBSK pulp real price logarithmic change for 1 to 6 months in the future. The final model has four variables: (1) the logarithmic change in cumulative three month NBSK deliveries divided by cumulative three month potential NBSK manufacturing capacity (PMC), (2) the logarithmic change in cumulative three month NBSK producer inventories divided by cumulative three month potential NBSK manufacturing capacity (PMC), (3) the 12 month logarithmic change in OECD industrial production (OECD IP), and (4) the deviation of current NBSK price from the estimated equilibrium price based on NBSK inventories divided by PMC.

Based on the anova (analysis of variance) *F*-statistic in table 3-6, all models are highly statistically significant. Like the *F*-statistic, also the adjusted coefficient of determination (adjusted R^2) rises considerably when forecasting period lengthens. As was discussed earlier, the coefficient of determination does not have a direct interpretation of whether a model is good or bad at forecasting. However, as the models presented in the table are very much alike, it is to some extent acceptable to compare the adjusted R^2 values between the models.

Even though at first it may be thought that the one month change should be easier to forecast than the six month change, it is, in fact, less easy to predict. Firstly, the random effects affecting the price change each month tend to have both negative and positive effects in six months, thus diminishing the random factor. Secondly, as pulp capacities are usually sold in advance, the pressure to change prices (observed in models' variables) may not actually affect the prices for some months. The rising adjusted R^2 values reflect the above.

Autocorrelation means that a model's consecutive error terms are often of the same sign. This in turn suggests that the model would be better if the error term of the previous observation would be included as a variable. With the pulp short term models, the usual measure of autocorrelation, the Durbin-Watson *d*-statistic, shows significant autocorrelation for models longer than 2 months. However, this statistic is useless without modifications, as it is most probable that the error terms of, e.g., the six month model are autocorrelated, as two consecutive forecasts are made five and six months before the later forecast, and thus there are four months of events affecting the price development before them.

Table 3-4: NBSK pulp short term price change forecasting models; one to six month models' variables, coefficients, t-statistics in parentheses, adjusted coefficient of determination, exact Durbin-Watson p-value presented as the probability level with which the model would be found autocorrelated, anova F-test p-value for the significance of the whole model, Chow test p-value for structural change, and the Goldfeld-Quant test p-value for heteroscedasticity.

	1 month	**2 month**	**3 month**	**4 month**	**5 month**	**6 month**
Constant	-0.0192	-0.0372	-0.0546	-0.0724	-0.0883	-0.1009
	(-2.66)***	(-3.83)***	(-4.78)***	(-5.71)***	(-6.30)***	(-6.40)***
3 mo. Deliveries /	-0.0653	0.0234	0.0970	0.2667	0.3548	0.3787
3 mo. PMC change	(-1.08)	(0.29)	(1.02)	(2.51)**	(3.02)***	(2.84)***
3 mo. Inventories /	-0.0954	-0.1617	-0.1748	-0.1570	-0.0941	-0.0329
3 mo. PMC change	(-2.31)**	(-2.89)***	(-2.65)**	(-2.13)**	(-1.15)	(-0.36)
12 mo. OECD IP change	0.9015	1.7254	2.5012	3.2847	4.0786	4.5918
	(3.37)***	(4.76)***	(5.86)***	(6.90)***	(7.68)***	(7.64)***
Deviation from Inv.-Price	-0.1339	-0.2603	-0.4127	-0.5702	-0.7511	-0.9138
equilibrium (x 1000)	(-3.04)***	(-4.36)***	(-5.87)***	(-7.27)***	(-8.61)***	(-9.22)***
Adjusted R^2	0.3334	0.5291	0.6291	0.7082	0.7404	0.7403
Autocorrelation p-value	0.4687	0.6504	0.7890	0.6021	0.6638	0.8104
F-statistic p-value	0.0104	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Chow test p-value	0.2808	0.6435	0.5571	0.2988	0.0978	0.0226
Goldfeld-Quant p-value	0.4181	0.0082	0.0013	0.0170	0.1753	0.4892

*** statistically significant at 1% level; ** at 5% level, * at 10% level

x 1000: coefficient value is expressed as 1000 times the true value

Instead of the usual *d*-statistic, an exact Durbin-Watson probability of rejecting the null hypothesis that there is no autocorrelation when it is true was calculated (see

White 1993, p. 71). For example, if the calculated probability is 0.4687, the model would not be deemed autocorrelated at the usual 5% or 10% level, but only at 46.9% or higher level. All models are clearly above the significant levels, and thus no adjustments for autocorrelation were necessary.

Variable analysis

Each of the pulp short term models' variables is analysed below. Some of the variables tested in the model but not included in the final model are explained first. The variables, their coefficients and test statistics are presented in table 3-6.

Intuitively, the previous *n*-month change in NBSK price should enter the models, as the price cycles are much longer than a few months and the direction of change seldom changes. However, when the three month change (because of the lack of monthly data, three month and six month changes behave more reliably than 1, 2, 4 or 5 month changes) was included in the models, it was not statistically significant. Of course, what really affects the pulp price is not the previous change in price but the current supply and demand, which are reflected in the other variables. Even so, the changes in supply and demand may not always have their full effect on price instantly, but gradually over time. Either this effect is relatively fast to take place, or the other variables' adjustments to these changes make price change insignificant in the model.

Including a lagged dependant variable (i.e. in this case NBSK price change) could also drive the model towards being more accurate in periods of continuing price rises and falls and less accurate in cycle direction changes. The changes in cycle direction are both the most important to forecast and the hardest to predict, not the least because there are quite few cycle turns in the time series data.

Other deviations from estimated equilibrium than the inventory-price did not have significant effects when entered into the model. Changes in paper prices and pulp actual production / PMC were also insignificant as variables.

3 month deliveries / 3 month PMC change

Changes in deliveries seem to have significant effect on price only after three months. The coefficient is positive (except in one month model, where it is insignificant), as was expected since rising deliveries are thought to imply rising demand. The gradual rise of the coefficient is partly due to it becoming more significant as a forecasting factor and partly to the fact that six month changes are usually larger than one month changes.

3 month inventories / 3 month PMC change

Opposite to deliveries, change in inventory level is a significant factor in the model at 5% level only for one to four month models. The sign of the coefficient is, again as expected, negative, as rising inventories mean that supply is greater than demand. The effect of the change in inventory level does not last very long or the longer effect is better captured by change in deliveries. These two variables are closely related, but a one-time shift in deliveries (assuming production level constant) affects to all inventory level changes thereafter. Furthermore, this also explains the fact that three month changes in inventory level are usually larger than respective changes in deliveries. Thus, smaller coefficients of inventory changes may have a bigger effect on the model than larger coefficients of deliveries changes.

12 month change in OECD industrial production

As it is widely accepted that pulp and paper price cycles are closely related to global business cycles, the high significance of the change in OECD industrial production is not surprising. The sign of the coefficient is positive as expected. This variable is lagged by one month, i.e. the twelve month change one month earlier than the other variables is used, because the statistics are not available as soon as the others.

Deviation from the estimated inventory-level based equilibrium price

As was suggested by previously made studies (especially Toppinen, Laaksonen, and Hänninen 1996) and many market participants interviewed, the co-integrating relationship between inventory level and price is a highly significant factor in the models. The importance and size of coefficients increase towards the longer models. For example, in December 1995, just before the sharpest drop ever in NBSK price, the NBSK real price (in Feb 1997 dollars) was \$953 and the equilibrium price based on inventory level (1.92 mill. tonnes) per P.M.C. (potential manufacturing capacity, 1.99 mill. tonnes) \$587. Thus the six month logarithmic change forecast[6] by this variable alone was -0.0009138 multiplied by (\$953-\$587) = -0.334, i.e. the forecast price in June 1996 was approximately \$685. The actual realised real price was, however, as low as \$525.

The two inventory level based variables in the model both work the same way - if inventory level rises, they predict NBSK price is going to fall. However, the three month change variable concentrates on short term changes, while the deviation from equilibrium is not much affected by small short term changes in inventory level. Thus, they seek to include both the level of inventories (indicating excess supply) and the direction of the development of inventories in the model.

Constant

Constant is negative in all short term models. Since there are four variables, it is difficult to determine why it should be negative. At least partly it may be explained by the fact that the average change of OECD industrial production is positive, as it has an upward trend, while the NBSK real price has not, and the constant is a balancing factor.

Coefficient stability

It is important to know whether model coefficients depend much on the estimation period, because if the coefficients vary a lot with different estimation periods, it is likely that the model is not valid outside the estimation period, i.e., it is not very useful for forecasting purposes. A Chow test was run for all models to find out if there

6 It should be noted that this forecast is actually made *ex post*, i.e., the model was estimated using the realised price and other

was a structural change during the estimation period, in other words whether the coefficients of a model estimated with data before a certain point of time and the same model estimated with data after that point of time were different.

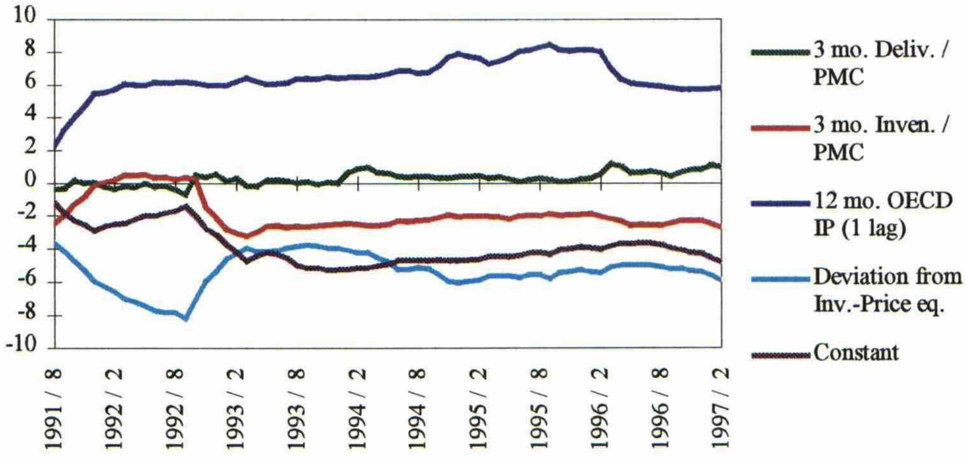
As the test statistics in table 3-6 for a half-way split Chow test show, for five to six month models there was evidence of structural change, and in one to four month models, coefficients are stable. When studying all pulp and paper models, it can be noted that the Chow test shows high statistical significance (5% level) for structural change in all models with forecasting period longer or equal to six months. This implies that either there are large structural changes in the longer term price behaviour, or half of the seven year period is not enough to reliably estimate the models with longer forecasting periods. While there certainly have been some amount of structural changes, just the fact that only one or two price cycles have evolved in both halves of the whole time period, suggest that it would be difficult to find a model the coefficients of which would be stable. Also, trying to estimate a 24 month change model with only 42 observations (three and a half years) will very probably yield unreliable results.

Subsequently, coefficient instability implies that the variables themselves might be different for models estimated with different time periods. This would mean that not only would a model's coefficients be unreliable after some time, but also it might have the wrong set of variables. The stability of the t-statistic of each variable in every model was tested by estimating the models with all possible seven year periods. The results for the three month model are presented in figure 3-15.

The t-statistics for the three month model's variables are quite stable after the beginning of 1993 and show that all variables except three months deliveries / PMC are highly statistically significant. Also it may be observed that the signs of all coefficients stay the same after the aforementioned point of time, since the sign of the t-statistic is always the same as the coefficient's.

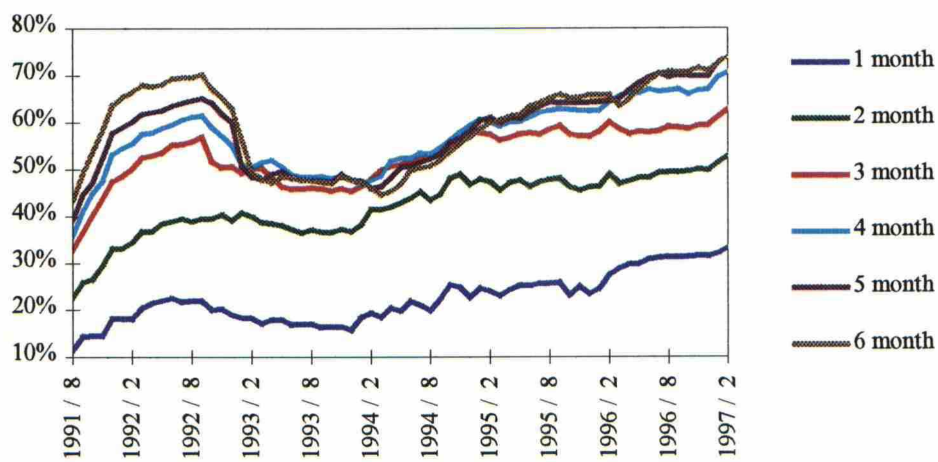
data for the "forecast" period, and thus gives better results than an *ex ante* model estimated without these data.

Figure 3-15: Stability of NBSK pulp three month price change forecasting model variables' t-statistics: t-statistics for coefficients of the model estimated from the previous 84 months



The results for the other pulp short term models were of similar nature. Thus it seems that the variables chosen reasonably reliably predict pulp price, even though it obviously can not be tested whether there exists even better variables, which were not included in the study.

Figure 3-16: Adjusted coefficient of determination of NBSK pulp short term price change forecasting models estimated from the previous 84 months



When computing the models for the t-statistics, the adjusted coefficient of determination (adjusted R^2) was also calculated for each model. The results, which are presented in figure 3-16, show how the explaining power of the models has changed through time. Since the statistic is based on *ex-post* forecasts, it does not give a proper view of the model's forecasting power, but of how well the model fits to the data. However, good explaining power means good forecasting power, if the coefficients are stable. It is interesting to note that after 1993 the explaining powers of all models have been rising, while it is often thought that forecasting has become more difficult. This may be due to the fact that pulp prices have become more market based and change more rapidly and thus reflect better the changes in models' variables. This does not, however, explain the large figures for 1992. The price trend reversal in the end of 1992 may at least partly explain the sudden drop. Confirming the earlier discussion of predictability of one vs. six month changes (see p. 51), the one and two month models have less explaining power than the others.

Besides the coefficient stability, another important consideration is model heteroscedasticity. Heteroscedasticity means that the "widths" of the distributions of the error terms in the model vary, i.e., error variance and thus expected error's distribution is not constant (Greene 1993, p. 384). While error variance is assumed constant (homoscedasticity) in the ordinary least squares linear regression models, heteroscedasticity causes the estimated model to be inefficient, although unbiased (Greene 1993, p. 387). As pulp price volatility has changed somewhat during the last ten years (see figure 1-7, p. 10), it was assumed that the models would be heteroscedastic and that a method such as GARCH would be needed for efficient estimation. However, as the Goldfeld-Quant test results show, the null hypothesis of homoscedasticity could be rejected at 10% level in the two, three and four month models only. When considering all pulp and paper models, approximately half were found heteroscedastic and the other half homoscedastic using this criterion.

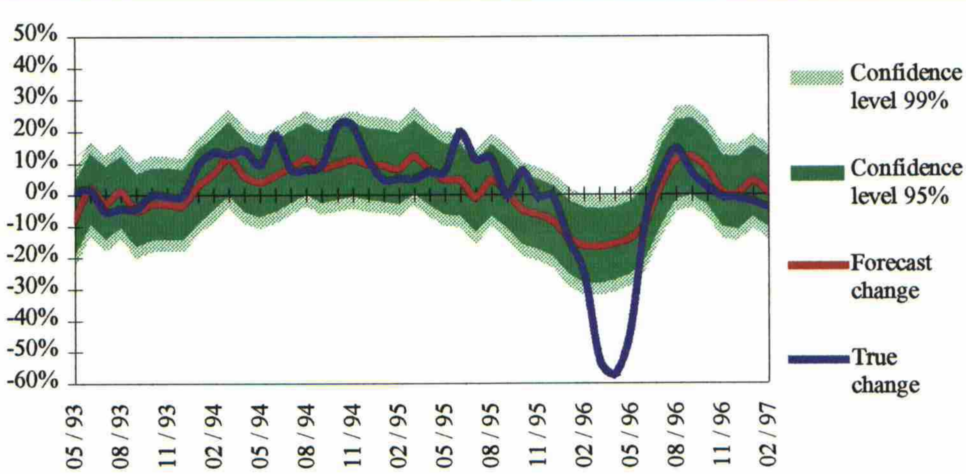
Even though and maybe even because the Goldfeld-Quant test reliability may suffer from the small number of observations - similar to the Chow test, the seven year period was divided in two observation sets with 42 observations in each - the probability of heteroscedasticity weakening the models and their results seems rather high.

All models were thus estimated using GARCH(1,1), which models the changes in variance using the previous (one lag) error term and variance in an autoregressive process. The results, however, were not as good as with the OLS linear regression. The variance equation was in most of the models non-stationary, i.e., the coefficient of the lagged variance term was greater than one. Also the forecast changes, when compared with the February, 1993 OLS models, were consistently farther from the realised changes. In conclusion, the existence of heteroscedasticity is vague and seems to differ even within the models. The OLS method may be to some extent inefficient, but as GARCH(1,1) yielded unstable variance equations and worse forecasting performance, it was rejected.

Forecasting Ability

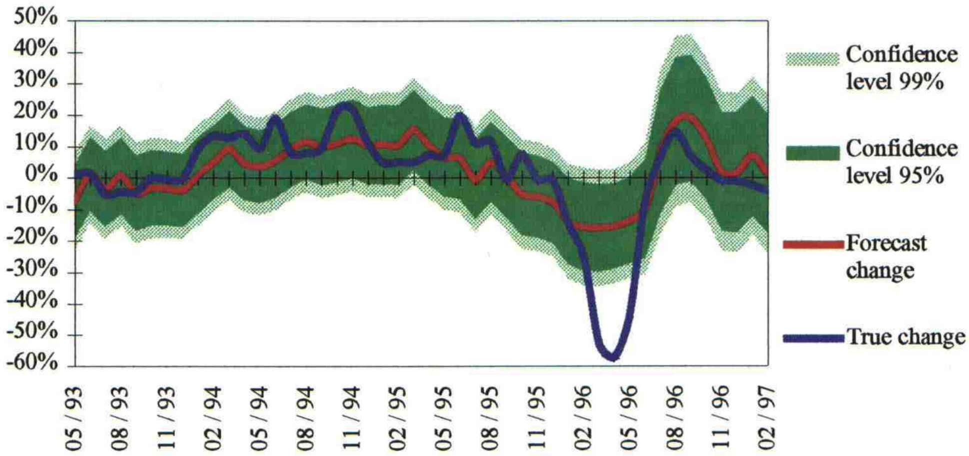
The actual forecasting abilities of the models will, of course, only be seen in the future. As there is no way to test the correctness of the models' forecasts, a "simulation" was done by estimating a model before the final model and then comparing the *ex-ante* forecasts computed with this model to the actual price changes.

Figure 3-17: Forecast NBSK pulp three month logarithmic price changes and 95% and 99% confidence levels calculated using coefficients estimated in February, 1993, and true three month logarithmic changes



The three month forecasts with 95% and 99% confidence levels and the true logarithmic change of NBSK price are shown in figure 3-17. The 95% confidence level means that 95% of observations should be within that range, but it should be noted that the confidence level is based on February, 1993 estimated model and is not adjusted for later changes in forecasting environment.

Figure 3-18: Forecast NBSK pulp three month logarithmic price changes and 95% and 99% confidence levels calculated using coefficients estimated at the time the forecast was conducted, and true three month logarithmic changes



Compared to figure 3-17 where the model is estimated with data available in February, 1993, in figure 3-18 the model is re-estimated each month with a new seven year period, and the forecast three months ahead and its confidence levels are thus based on the most recent set of data. The comparison of these two figures and the data behind them shows if there is any significant advantage to be gained by re-estimating the model monthly.

As previously discussed, the first half of 1996 saw the by far sharpest drop in pulp price, so it was assumed that the February, 1993 estimated model would not be able to predict this sudden fall too well. Figure 3-17 shows that even though at other times being rather close to the true change, the forecasts for March, April and May, 1996 are far from the realised change. In these three months, the change in price was also clearly outside the 99% confidence level range.

The constantly re-estimated models perform at other times very similarly to the February, 1993 estimated model, but in the beginning of 1996 the re-estimated models' confidence level ranges widen. Judging by the results of the three month model, constant re-estimation is not too important. Both methods are clearly a lot better than naive forecasts of zero change and previous observed change.

3.3.3 Pulp Long Term

Pulp long term models forecast NBSK pulp real price logarithmic change for 9, 12, 18 and 24 months in the future. The final model has three variables: (1) the 12 month logarithmic change in OECD industrial production (OECD IP), (2) the deviation of current NBSK price from the estimated equilibrium price based on NBSK deliveries divided by PMC, and (3) the deviation of current NBSK price from the estimated equilibrium price based on NBHK real price.

Table 3-5: NBSK pulp long term price change forecasting models; 9, 12, 18 and 24 month models' variables, coefficients, t-statistics in parentheses, adjusted coefficient of determination, exact Durbin-Watson p-value presented as the probability level with which the model would be found autocorrelated, anova F-test p-value for the significance of the whole model, Chow test p-value for structural change, and the Goldfeld-Quant test p-value for heteroscedasticity.

	9 month	**12 month**	**18 month**	**24 month**
Constant	-0.1791	-0.1855	-0.1788	-0.1474
	(-10.00)***	(-9.19)***	(-6.53)***	(-3.76)***
12 mo. OECD IP change	7.6841	7.3343	3.7091	-0.7904
	(11.49)***	(9.71)***	(3.83)***	(-0.60)
Deviation from Del.-Price eq.	-1.5722	-2.0261	-2.6129	-2.5170
(x 1000)	(-16.12)***	(-18.00)***	(-15.90)***	(-9.74)***
Deviation from NBSK-NBHK eq.	0.3172	0.9456	1.8956	1.2193
(x 1000)	(1.37)	(3.62)***	(5.67)***	(2.46)**
Adjusted R^2	0.8063	0.8264	0.7984	0.6702
Autocorrelation p-value	0.7114	0.2760	0.8340	0.9840
F-statistic p-value	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Chow test p-value	0.0222	0.0006	< 0.0001	< 0.0001
Goldfeld-Quant p-value	0.1765	0.1675	< 0.0001	0.0423

*** statistically significant at 1% level; ** at 5% level, * at 10% level

x 1000: coefficient value is expressed as 1000 times the true value

All anova F-statistics are below 0.01% in significance. Also the adjusted R^2 statistics are rather high; the 12 month model's adjusted R^2 of 0.8264 is the highest among pulp models. The models seem to weaken a little after 12 months, as the adjusted R^2 drops as do the t- and F-statistics (not observable in the table, as p-values are so small).

All autocorrelation statistics show no evidence of autocorrelation, but according to the Chow test there is a structural change in all the models. Heteroscedasticity is also suggested to exist in 18 and 24 month models (Goldfeld-Quant test). See pp. 53-57 of the chapter on pulp short term model for a more thorough discussion of these statistical properties.

Variable analysis

Each of the pulp long term models' variables is analysed below. Some variables, which were tested in the model but not included in the final model, are explained first. The variables, their coefficients and test statistics are presented in table 3-7.

Considering the rather long forecasting horizon of the longer term models, it is understandable that the short term changes in key variables like inventories and deliveries do not explain the long term changes in pulp price. Nor do the previous changes in the price itself, as was the case with the short term models. Longer term changes in these variables were also insignificant as forecasting variables, when the deviations from equilibrium level based on the same variables were added to the model.

As the deviation from the estimated inventory-based equilibrium price is significant in all other models, including long term paper models, it is surprising that it is insignificant in this model. It was assumed that the longer term pulp models would be the ones where this variable would be most important, as the deviations from equilibria are usually better in long term forecasting than short term. However, the inclusion of the deviation from the estimated deliveries-based equilibrium price made the inventory-based variable insignificant. Paper price-based variables were also useless as predictors.

12 month change in OECD industrial production

OECD IP is highly significant in 9, 12 and 18 month models, but insignificant in the 24 month model. This is probably due to the overall difficulty of forecasting this far, as all variables' *t*-statistics are much lower than in other models. Because the coefficients are of roughly the same size, the standard errors of the variables must be larger, indicating the difficulty.

Deviation from the estimated deliveries-based equilibrium price

The co-integrating dependence between deliveries and price is highly statistically significant in all models. While it was surprising that the inventories-based equivalent of this variable did not enter the model, the relationship of these two variables must be noted. If NBSK price is below deliveries-based equilibrium level, deliveries are most probably above average, as price and deliveries have positive correlation. If deliveries are above average, they are also above average production level, and inventories decrease. Hence, it may be thought that deliveries predict inventory level development, and so may have good long term forecasting power.

Deviation from the estimated NBHK price-based equilibrium price

Judging by the figures presented earlier, there exists a very tight relationship between NBSK and NBHK pulp prices. Usually, NBSK price is $20-$50 above the NBHK price. However, sometimes the prices depart further from each other or NBHK price tops NBSK price, and then demand starts to shift towards the cheaper (compared to normal price difference) quality. This shift causes that the price difference tends to grow or shrink back to normal levels again.

Accordingly, if NBSK price is above the estimated NBHK price-based equilibrium, it is inclined to fall and the NBHK price to rise. But the coefficient is positive in all models, which suggests opposite behaviour. It does not seem likely that the deviation from equilibrium would tend to grow, however. There are two possible explanations for the sign of the coefficients: (1) NBSK price changes may lead NBHK price changes and predict the "overall" pulp price movement, or (2) this variable and the other variables have together a more complex relationship and the sign of one variable may partly depend on that relationship.

Of these explanations, the latter seems more likely. If the first one were correct, previous changes in NBSK price would be better than this variable in forecasting. There is also no evidence of any lags in NBHK prices in the data. This variable can be seen as working together with the deliveries-based variable.

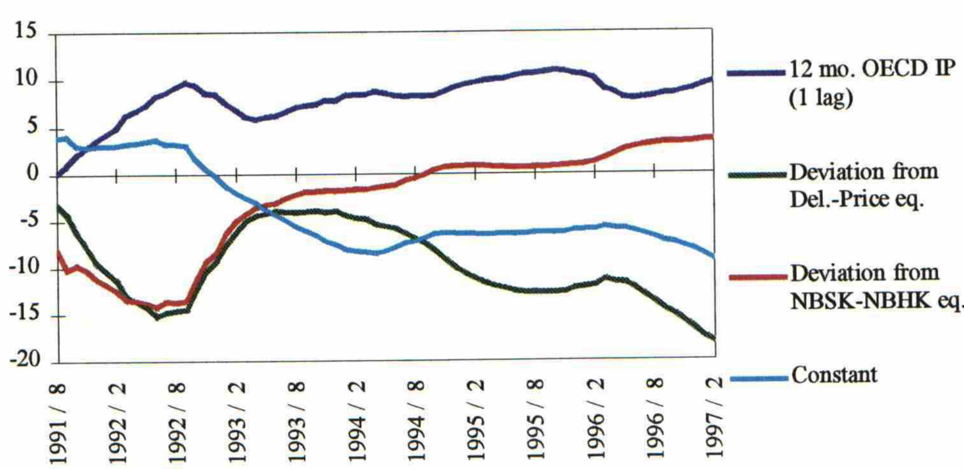
Constant

Constant term is negative in all models, probably offsetting the 12 month OECD IP change as explained earlier.

Coefficient stability

Besides the statistics presented before, coefficient stability was again studied by drawing the *t*-statistics of consecutively estimated models (figure 3-19).

Figure 3-19: Stability of NBSK pulp twelve month price change forecasting model variables' t-statistics: t-statistics for coefficients of the model estimated from the previous 84 months



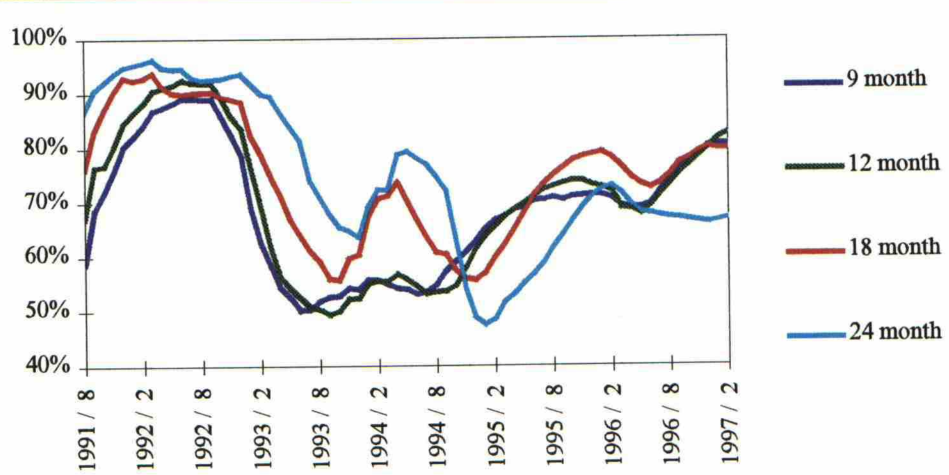
Compared to the three month model presented in figure 3-15, the *t*-statistics of the twelve month model are a lot more volatile. Even after 1993, the significance of the

NBSK price deviation from deliveries based equilibrium price increases substantially, while the NBSK price deviation from NBHK price based equilibrium price changes signs from negative to positive. Similar behaviour applies to all long term models.

Thus, with the Chow test results strongly suggesting structural change, the usability of the long term models is questionable. It seems that the model depends rather much on the point of estimation, and hence may not be valid for the present time, as it gives equal weight to observations made seven years ago and one month ago. A weighted least squares method (see e.g. Greene 1993) instead of ordinary least squares would give less weight to historical observations, but it is only a partial solution. The most probable reason for the model's instability is that there are factors not included in the model which affect price development. This study has not been able to find these factors, and even though the factors were found, they might be difficult to quantify (e.g. strikes and strike threats at pulp and paper mills).

The adjusted coefficients of determination show similar behaviour to the short term models. In 1992 they were very high, and then dropped to between 50% and 80%. Differences between various length models are fairly small.

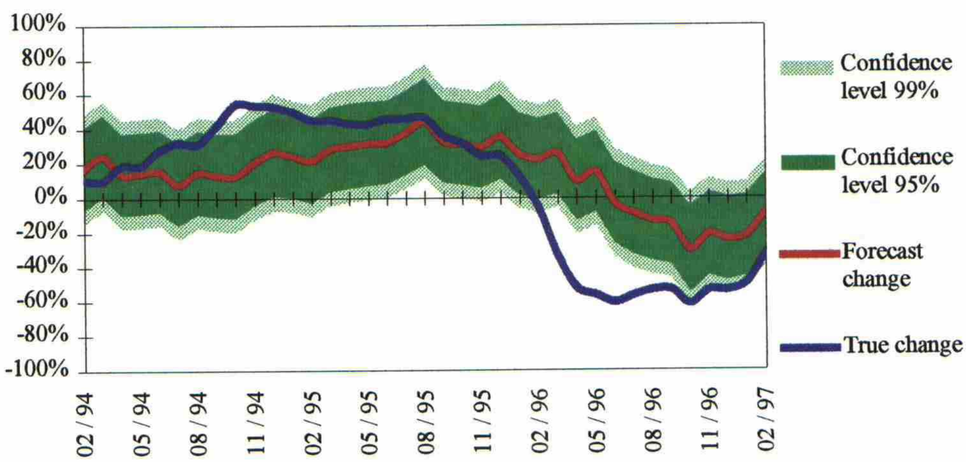
Figure 3-20: Adjusted coefficient of determination of NBSK pulp long term price change forecasting models estimated from the previous 84 months



Forecasting Ability

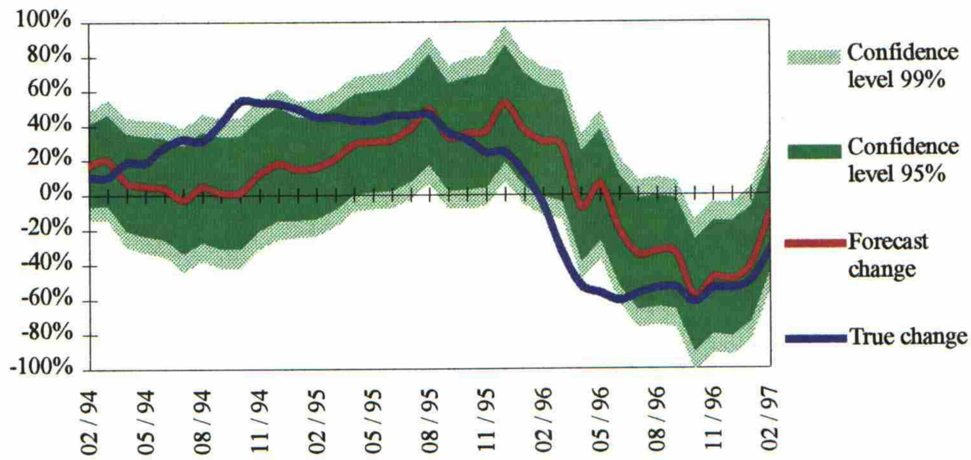
The forecasting ability of the twelve month model can be evaluated using figures 3-21 and 3-22 identically as with the three month model before. Again, the model is unable to forecast the sudden drop in NBSK price in the beginning of 1996. The differences between the re-estimated model and the February, 1993 model are relatively small, but the re-estimated model is, as was the case with the three month model, significantly better at forecasting changes after March, 1996. In October 1996, when NBSK price peaked at $1000 per ton, it predicted the twelve month price drop almost exactly correct.

Figure 3-21: Forecast NBSK pulp twelve month logarithmic price changes and 95% and 99% confidence levels calculated using coefficients estimated in February, 1993, and true twelve month logarithmic changes



Even though the model is again better than naive forecasts, its reliability is not as good as the short term models. Especially the 24 month model is weak and unstable.

Figure 3-22: Forecast NBSK pulp twelve month logarithmic price changes and 95% and 99% confidence levels calculated using coefficients estimated at the time the forecast was conducted, and true twelve month logarithmic changes



3.3.4 Uncoated Fine Paper

Uncoated fine paper models forecast uncoated fine paper real price logarithmic change for 3, 6, 12 and 24 months in the future. The model for 3 and 6 months has five variables, and the model for 12 and 24 months has three. The short term model variables are: (1) the 12 month logarithmic change in OECD industrial production (OECD IP), (2) the logarithmic change in cumulative three month NBSK producer inventories divided by cumulative three month potential NBSK manufacturing capacity (PMC), (3) the deviation of current NBSK price from the estimated equilibrium price based on NBSK inventories divided by PMC, (4) the deviation of current uncoated fine paper price from the estimated equilibrium price based on NBSK real price, and (5) the deviation of current uncoated magazine paper price from the estimated equilibrium price based on uncoated fine paper real price. The long term model uses variables 1, 3 and 4 of the above.

All anova *F*-statistics are highly significant. Also the adjusted R^2 statistics are rather high except for the 24 month model; the 6 month model's adjusted R^2 of 0.8411 is the highest among all pulp and paper models.

All autocorrelation statistics show no evidence of autocorrelation, but according to the Chow test there is a structural change in all the models. According to the Goldfeld-Quant test results, the 6 and 24 month models are heteroscedastic, but the 3 and 12 month models are not. See pp. 53-57 of the chapter on pulp short term model for a more thorough discussion of these statistical properties.

Table 3-6: Uncoated fine paper price change forecasting models; 3, 6, 12 and 24 month models' variables, coefficients, t-statistics in parentheses, adjusted coefficient of determination, exact Durbin-Watson p-value presented as the probability level with which the model would be found autocorrelated, anova F-test p-value for the significance of the whole model, Chow test p-value for structural change, and the Goldfeld-Quant test p-value for heteroscedasticity.

	3 month	6 month	12 month	24 month
Constant	-0.0069	-0.0582	-0.0669	-0.0086
	(-0.82)	(-4.36)***	(-3.05)***	(-0.22)
12 mo. OECD IP change	1.8180	4.6100	4.7704	-2.5321
	(6.10)***	(9.14)***	(6.16)***	(-1.80)*
3 mo. Inventories /	-0.1140	-0.0335		
3 mo. PMC change	(-3.27)***	(-0.59)		
Deviation from Inv.-Price eq.	-0.3651	-0.7341	-1.3070	-1.6935
(x 1000)	(-8.27)***	(-10.60)***	(-11.88)***	(-6.60)***
Deviation from UFP-NBSK eq.	0.7572	1.0150	1.8467	1.7503
(x 1000)	(8.55)***	(7.27)***	(5.09)***	(2.07)**
Deviation from UMP-UFP eq.	0.2586	0.0466		
(x 1000)	(3.97)***	(0.43)		
Adjusted R^2	0.8039	0.8411	0.7083	0.4374
Autocorrelation p-value	0.9526	0.9947	0.9944	0.9979
F-statistic p-value	< 0.0001	< 0.0001	< 0.0001	0.0010
Chow test p-value	0.0322	< 0.0001	< 0.0001	< 0.0001
Goldfeld-Quant p-value	0.1650	0.0048	0.2671	0.0012

*** statistically significant at 1% level; ** at 5% level, * at 10% level

x 1000: coefficient value is expressed as 1000 times the true value

Variable analysis

Each of the uncoated fine paper models' variables is analysed below. The variables, their coefficients and test statistics are presented in table 3-8.

Like the preliminary analysis showed, NBSK price changes do not predict uncoated fine paper (UFP) price changes. Similarly to the NBSK short term model, lagged UFP price changes were also insignificant as predictors.

12 month change in OECD industrial production

OECD IP is highly significant in all models except in the 24 month model, where it is significant at the 10% level. The inability of this variable to forecast as far as two years ahead was already seen with the pulp long term model. The coefficients are positive in the first three models and negative in the 24 month model.

3 month inventories / 3 month PMC change

The three month inventories / PMC change is used only with the short term models, identically to pulp models. The variable is significant only with the three month model, which is also similar to the pulp short term models. As expected, its coefficients are negative implying rising prices when inventories fall.

NBSK price deviation from the estimated NBSK inventories-based equilibrium price

While this NBSK inventory-based variable was insignificant when forecasting long term pulp price changes, it is significant in UFP long term models. The deliveries-based equivalent, which was used with pulp models, was not as good a predictor for UFP. The variable is very highly statistically significant and has negative coefficients as expected. Although the coefficients are smaller in absolute value than those of the other deviation-based variables, its larger absolute deviations from equilibrium actually cause it to have more influence on the forecast than the others.

Uncoated fine paper price deviation from the estimated NBSK price-based equilibrium price

A positive UFP price deviation from the estimated NBSK price-based equilibrium price suggests that the UFP price is too high or the NBSK price too low. These prices tend to return to their equilibrium, i.e. UFP price tends to fall and/or NBSK price tends to rise. However, the coefficients of this variable are all positive, implying opposite behaviour. The results are similar to NBSK-NBHK equilibrium in pulp long term models. The reason for positive coefficients, too, is probably the same: there exists a more complex relationship between the variables than the coefficients are able to unveil.

Uncoated magazine paper (UMP) price deviation from the estimated uncoated fine paper price-based equilibrium price

A positive UMP price deviation from the estimated UFP price-based equilibrium means that UMP price is above equilibrium and/or UFP price is below equilibrium. Therefore it is as expected that the coefficients are positive, because the variables are likely to converge towards equilibrium. This variable is included only in the short term models, and significant in the three month model only.

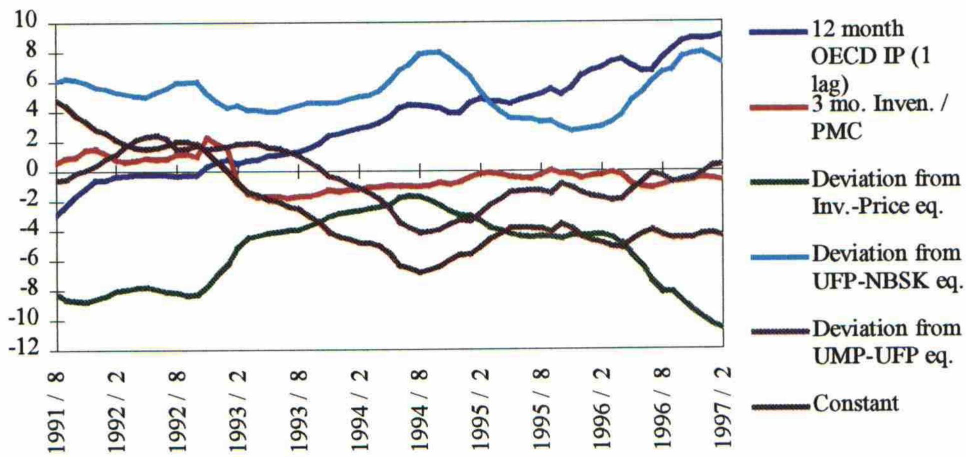
Constant

Constant term is negative in all models, while significantly so in only the six and twelve month ones. The negativity is again probably offsetting the 12 month OECD IP change.

Coefficient stability

In addition to statistical tests, coefficient stability can be evaluated with figure 3-23, where the *t*-statistics for the monthly re-estimated six month models are shown. After 1993, the coefficients do not change signs clearly and seem relatively stable. The significance of both the twelve month change in OECD IP and the NBSK price deviation from estimated NBSK price - NBSK inventories equilibrium rises significantly after 1993. The results were rather much the same for the other models, except that the longer models did not include two of the variables.

Figure 3-23: Stability of Uncoated Fine Paper six month price change forecasting model variables' t-statistics: t-statistics for coefficients of the model estimated from the previous 84 months



Forecasting Ability

The forecasting ability of the six month model can be evaluated using figures 3-24 and 3-25. The model only partly forecasts the prices rise in 1994-1995, while it does a little bit better when forecasting the price drop in 1996. Notably, the re-estimated model actually does worse than February 1993 model in 1995, predicting prices to fall then they rose.

Figure 3-24: Forecast Uncoated Fine Paper six month logarithmic price changes and 95% and 99% confidence levels calculated using coefficients estimated in February, 1993, and true six month logarithmic changes

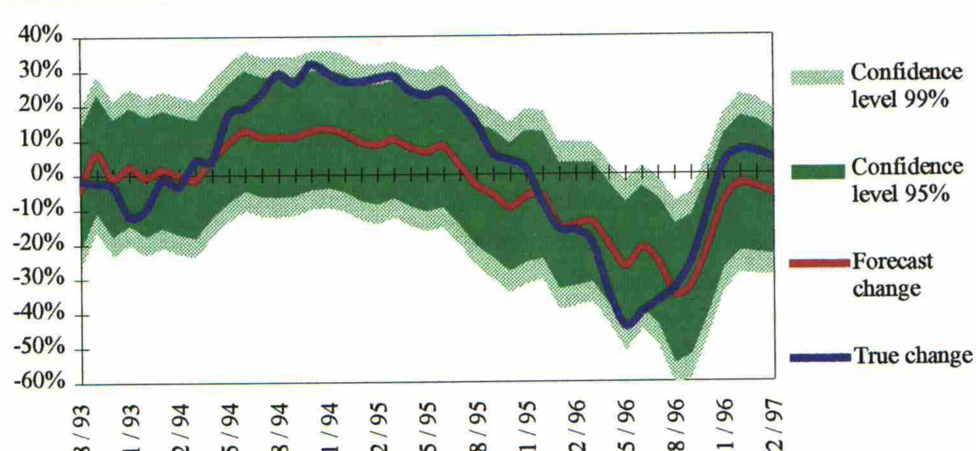
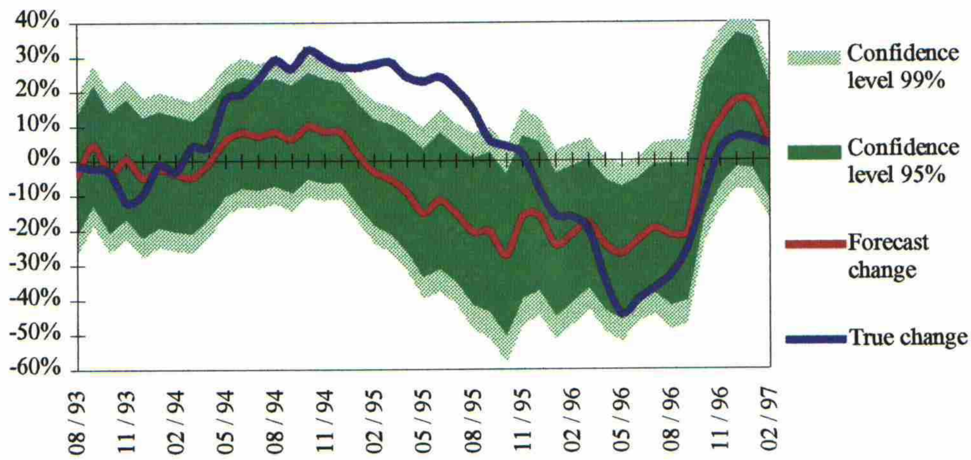


Figure 3-25: Forecast Uncoated Fine Paper six month logarithmic price changes and 95% and 99% confidence levels calculated using coefficients estimated at the time the forecast was conducted, and true six month logarithmic changes



Overall, the re-estimated model does relatively well if year 1995 is not taken into account. The poor performance in 1995, however, casts doubts to its credibility.

3.3.5 Uncoated Magazine Paper

Uncoated magazine paper models forecast uncoated magazine paper real price logarithmic change for 3, 6, 12 and 24 months in the future. The model for 3 and 6 months has three variables, and the model for 12 and 24 months has four. The short term model variables are: (1) the deviation of current NBSK price from the estimated equilibrium price based on NBSK inventories divided by PMC, (2) the deviation of current uncoated fine paper price from the estimated equilibrium price based on NBSK real price, and (3) the deviation of current uncoated magazine paper price from the estimated equilibrium price based on uncoated fine paper real price. The long term model also uses (4) the deviation of current NBSK price from the estimated equilibrium price based on NBHK real price.

All anova F-statistics are once again highly significant. The adjusted R^2 statistics are generally not as high as for the previously presented models, but the twelve month model's adjusted R^2 of 0.7743 is relatively high.

All autocorrelation statistics again show no evidence of autocorrelation, but according to the Chow test there is a structural change in all models but the three month model. The Goldfeld-Quant test results indicate that all models except the twelve month model are heteroscedastic. Once again, see pp. 53-57 of the chapter on pulp short term model for a more thorough discussion of these statistical properties.

Table 3-7: Uncoated Magazine Paper price change forecasting models; 3, 6, 12 and 24 month models' variables, coefficients, t-statistics in parentheses, adjusted coefficient of determination, exact Durbin-Watson p-value presented as the probability level with which the model would be found autocorrelated, anova F-test p-value for the significance of the whole model, Chow test p-value for structural change, and the Goldfeld-Quant test p-value for heteroscedasticity.

	3 month	**6 month**	**12 month**	**24 month**
Constant	0.0188	0.0366	0.0532	0.0128
	(3.02)***	(4.25)***	(4.43)***	(0.50)
Deviation from Inv.-Price eq.	-0.1716	-0.3857	-1.1476	-2.1876
(x 1000)	(-4.40)***	(-7.15)***	(-13.51)***	(-9.89)***
Deviation from UFP-NBSK eq.	0.1629	0.4196	0.9894	2.2295
(x 1000)	(1.78)*	(3.31)***	(4.32)***	(4.30)***
Deviation from UMP-UFP eq.	0.5152	0.9646	1.7098	1.4926
(x 1000)	(9.85)***	(13.21)***	(14.42)***	(5.44)***
Deviation from NBSK-NBHK eq.			0.6759	1.6119
(x 1000)			(3.75)***	(4.33)***
Adjusted R^2	0.5495	0.6957	0.7743	0.6219
Autocorrelation p-value	0.5862	0.9998	0.9974	0.9880
F-statistic p-value	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Chow test p-value	0.2613	0.0067	0.0004	< 0.0001
Goldfeld-Quant p-value	0.0014	0.0001	0.3520	0.0001

*** statistically significant at 1% level; ** at 5% level, * at 10% level
x 1000: coefficient value is expressed as 1000 times the true value

Variable analysis

Each of the uncoated magazine paper models' variables is analysed below. Some variables, which were tested in the model but not included in the final model, are explained first. The variables, their coefficients and test statistics are presented in table 3-9.

Like the preliminary analysis showed, NBSK price changes do not predict uncoated magazine paper (UMP) price changes. Lagged UFP and UMP price changes were also insignificant as predictors. Most unexpectedly, however, the twelve month change in OECD industrial production is insignificant if added to the model. It was assumed, and also seen with other models, that OECD IP would be one of the most important variables explaining and forecasting demand for all products. Since OECD IP and short term changes are not included, all models' variables are equilibrium-based (co-integrating) variables.

NBSK price deviation from the estimated NBSK inventories-based equilibrium price

The NBSK price and inventories equilibrium based variable is highly significant in all models. The coefficients are, as expected, negative and their absolute values the greater the longer the model. Compared to pulp short term models and uncoated fine paper models, the absolute values of the coefficients are smaller except in the 24 month model. Even though the choice of other variables affects these values to some extent, it seems reasonable that of the aforementioned models, this variable has the smallest effect on the UMP price.

Uncoated fine paper price deviation from the estimated NBSK price-based equilibrium price

The coefficients, statistically significant at 10% level for the three month model and at 1% for the other models, are positive just like in the uncoated fine paper models presented before. The interpretation of this variable, which is not directly linked to uncoated magazine paper, is that when it is positive, uncoated fine paper prices will fall in the future and uncoated magazine paper price are likely to follow. However, then the coefficients should be negative. The reason for the unexpected sign is probably that the relationship between the variables is more complex, as in the uncoated fine paper models.

Uncoated magazine paper (UMP) price deviation from the estimated uncoated fine paper price-based equilibrium price

Alike the uncoated fine paper models, the coefficients of this variable are positive. However, now the variable must be interpreted the opposite way, as the variable being forecast is UMP price, not UFP price. Hence, the positive sign is again thought to be due to a complex relationship between the variables, while negative signs were expected. The variable is also highly statistically significant in all models.

Deviation of NBSK price from the estimated NBHK price-based equilibrium price

The deviation of NBSK price from the estimated equilibrium NBSK price based on the NBHK price is only included in 12 and 24 month models, where it is highly significant. The coefficients are positive, but, with the limited data set available, it is not easy to determine why. As uncoated magazine paper is made mostly of mechanical pulp, it may be that the relationship between mechanical pulp and NBHK pulp would better explain the price movements.

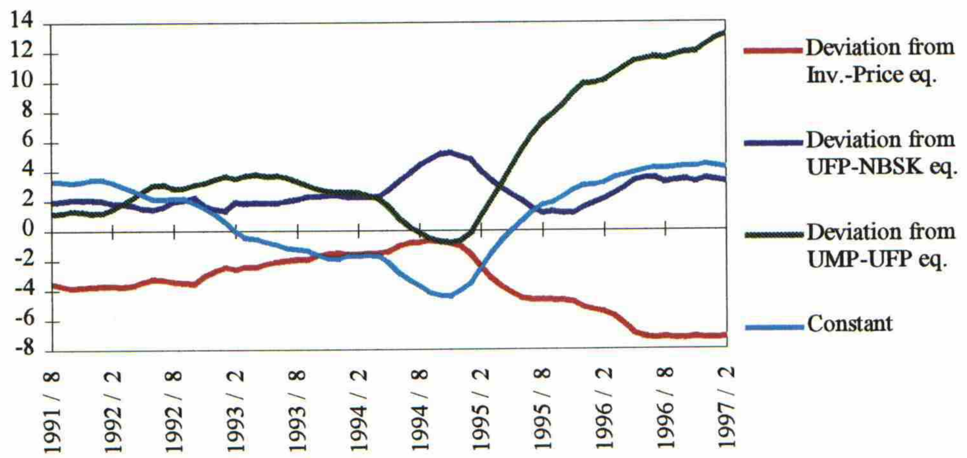
Constant

Unlike other models, the constant term is positive in all uncoated magazine paper models, significantly so in all but the 24 month model. The omission of the 12 month OECD IP change from the models causes the difference.

Coefficient stability

In addition to statistical tests, coefficient stability can be evaluated with figure 3-26, where the *t*-statistics for the monthly re-estimated six month models are shown. Before 1995, the *t*-statistics are quite stable, but after that the NBSK-NBSK inventory and UFP-UMP based variables' statistics rise markedly. The variables do not change signs significantly, so the model seems relatively stable. The results for the other models were rather similar.

Figure 3-26: Stability of Uncoated Magazine Paper six month price change forecasting model variables' t-statistics: t-statistics for coefficients of the model estimated from the previous 84 months



Forecasting Ability

The forecasting ability of the six month model can be evaluated using figures 3-27 and 3-28. Like the uncoated fine paper models, the models were not able to adequately forecast the price rise of 1995, and the re-estimated model's performance was very poor in that year. However, before and after 1995 the model predicted uncoated magazine paper price movements very well.

Figure 3-27: Forecast Uncoated Magazine Paper six month logarithmic price changes and 95% and 99% confidence levels calculated using coefficients estimated in February, 1993, and true six month logarithmic changes

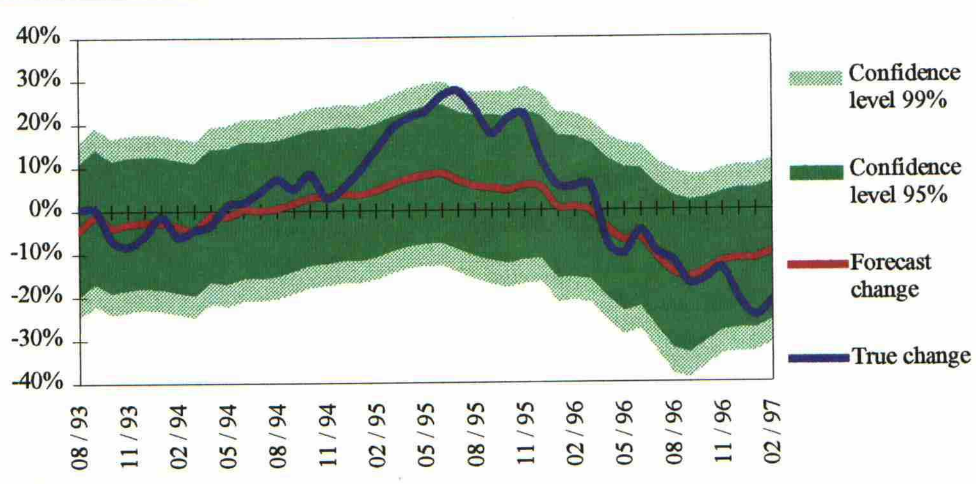
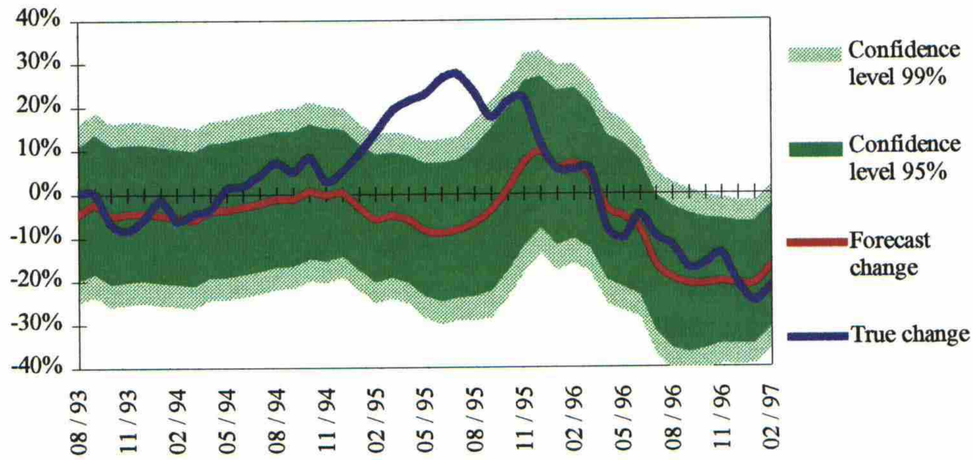


Figure 3-28: Forecast Uncoated Magazine Paper six month logarithmic price changes and 95% and 99% confidence levels calculated using coefficients estimated at the time the forecast was conducted, and true six month logarithmic changes



3.3.6 Newsprint

Newsprint models forecast newsprint real price logarithmic change for 3, 6, 12 and 24 months in the future. The model for 3 and 6 months has three variables, and the model for 12 and 24 months has four. The short term model variables are: (1) the 12 month logarithmic change in OECD industrial production (OECD IP), (2) the deviation of current NBSK price from the estimated equilibrium price based on NBSK inventories divided by PMC, and (3) the deviation of current uncoated magazine paper price from the estimated equilibrium price based on uncoated fine paper real price. The long term model also uses variables (1) and (2) of the above plus (3) the deviation of current newsprint (NP) price from the estimated equilibrium price based on uncoated magazine paper real price, and (4) the deviation of current NBSK price from the estimated equilibrium price based on NBHK real price.

Again, all anova *F*-statistics are highly significant. The adjusted R^2 statistics are generally the lowest of all models, but the six and twelve month model's adjusted R^2 of 0.6656 and 0.7095, respectively, are relatively high.

All autocorrelation statistics again show no evidence of autocorrelation, but according to the Chow test there is a structural change in all models but the three month model. The Goldfeld-Quant test results indicate that all models are heteroscedastic. See pp. 53-57 of the chapter on pulp short term model for a more thorough discussion of these statistical properties.

Table 3-8: Newsprint price change forecasting models; 3, 6, 12 and 24 month models' variables, coefficients, t-statistics in parentheses, adjusted coefficient of determination, exact Durbin-Watson p-value presented as the probability level with which the model would be found autocorrelated, anova F-test p-value for the significance of the whole model, Chow test p-value for structural change, and the Goldfeld-Quant test p-value for heteroscedasticity.

	3 month	**6 month**	**12 month**	**24 month**
Constant	0.0037	-0.0108	-0.0933	-0.2096
	(0.36)	(-0.84)	(-3.96)***	(-4.28)***
12 mo. OECD IP change	0.6362	2.0270	6.9844	6.4187
	(1.74)*	(4.23)***	(11.38)***	(4.72)***
Deviation from Inv.-Price eq. (x 1000)	-0.1401	-0.2773	-0.5787	-1.5934
	(-2.74)***	(-4.31)***	(-6.38)***	(-5.82)***
Deviation from UMP-UFP eq. (x 1000)	0.4371	0.6595		
	(5.21)***	(6.01)***		
Deviation from NP-UMP eq. (x 1000)			0.0117	4.2143
			(0.02)	(2.72)***
Deviation from NBSK-NBHK eq. (x 1000)			0.3878	1.5316
			(1.60)	(2.83)***
Adjusted R^2	0.4579	0.6656	0.7095	0.5313
Autocorrelation p-value	0.9942	0.9961	0.9840	1.0000
F-statistic p-value	< 0.0001	< 0.0001	< 0.0001	0.0005
Chow test p-value	0.1663	0.0045	< 0.0001	< 0.0001
Goldfeld-Quant p-value	0.0004	0.0002	0.0067	0.0170

*** statistically significant at 1% level; ** at 5% level, * at 10% level
x 1000: coefficient value is expressed as 1000 times the true value

Variable analysis

Each of the newsprint models' variables is analysed below. The variables, their coefficients and test statistics are presented in table 3-10.

12 month change in OECD industrial production

The twelve month change in OECD IP is significant in all models and has positive coefficients. It seems especially important when forecasting twelve month price changes; the coefficient is greater than in the 24 month model, and much more significant. Unlike other models, however, it is still significant and its coefficient positive in the 24 month model.

NBSK price deviation from the estimated NBSK inventories-based equilibrium price

The coefficients of this NBSK-based variable are negative as expected, and highly statistically significant. Even though usually less than 15% of newsprint is NBSK pulp (see table 1-4, p. 8), the correlation of all studied pulp and paper qualities and perhaps even more the correlation of mechanical pulp, the main ingredient of newsprint, and NBSK pulp prices causes the predicting ability of this variable. However, the coefficients are smaller than in other models, as the relationship is weaker — although the choice of other variables also affects the coefficient magnitudes.

Uncoated magazine paper (UMP) price deviation from the estimated uncoated fine paper price-based equilibrium price

This variable is only included in the short term model, where it is highly significant. The positive sign suggests that newsprint price is more tied to uncoated fine paper price than uncoated magazine paper price, because when UMP is higher than its UFP-based equilibrium level, newsprint price tends to rise. However, it is not possible to say whether this is the case or if the positive sign is merely because of a complex relationship between variables as before — newsprint is closer to magazine paper than fine paper if judged by ingredients.

Newsprint (NP) price deviation from the estimated uncoated magazine paper price-based equilibrium price

The newsprint price deviation from UFP price-based equilibrium is not included in the short term models, and is significant in the 24 month model alone. It has virtually no effect on the 12 month model, even though included because of its importance in the 24 month model. The coefficient in the 24 month model is positive, again probably because of a complex relationship between the variables.

Deviation of NBSK price from the estimated NBHK price-based equilibrium price

Like the previous variable, this one is included only in the 12 and 24 month models, where it is significant in the latter. The coefficients are positive and not easy to interpret, as explained when discussing the uncoated magazine paper models.

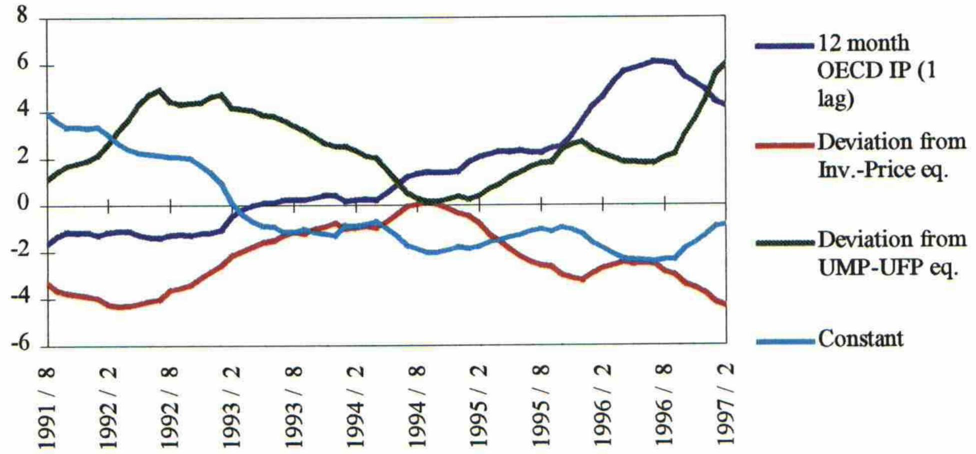
Constant

The constant term is positive in the three month model and negative in other models. It has significance only in the longer term models.

Coefficient stability

In addition to statistical tests, coefficient stability can be evaluated with figure 3-29, where the *t*-statistics for the monthly re-estimated six month models are shown. Overall, the statistics are volatile, but do not change signs significantly.

Figure 3-29: Stability of Newsprint six month price change forecasting model variables' t-statistics: t-statistics for coefficients of the model estimated from the previous 84 months



Forecasting Ability

The forecasting ability of the six month model can be evaluated using figures 3-30 and 3-31. Like the other paper models, the models were not able to forecast the strong price rise of 1995. The 1996 price drop was, however, very well forecast by both models, although in the end of 1996 the re-estimated model performed worse. Overall, the performances of the February, 1993 model and the constantly re-estimated model are quite similar.

Figure 3-30: Forecast Newsprint six month logarithmic price changes and 95% and 99% confidence levels calculated using coefficients estimated in February, 1993, and true six month logarithmic changes

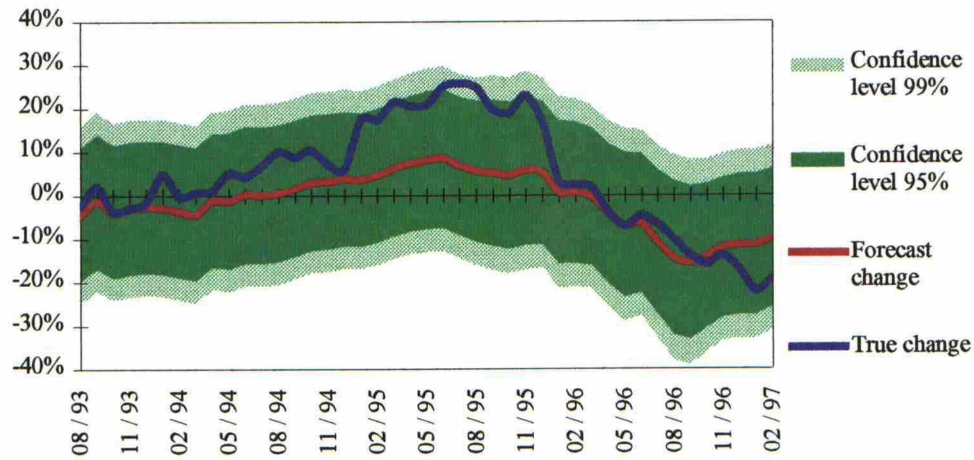
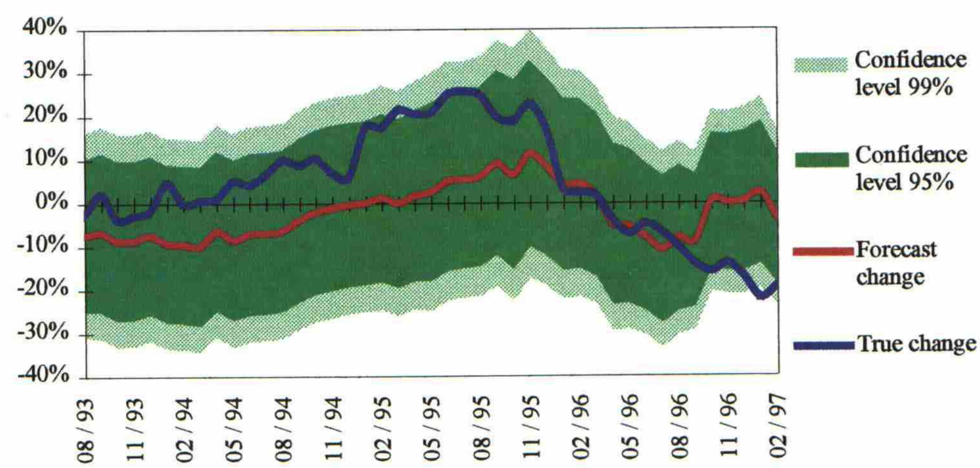


Figure 3-31: Forecast Newsprint six month logarithmic price changes and 95% and 99% confidence levels calculated using coefficients estimated at the time the forecast was conducted, and true six month logarithmic changes



3.3.7 Overview of the Models

Overall, the models are largely based on the following factors: OECD industrial production growth, NBSK pulp inventories, NBSK pulp deliveries, and the co-integrating relationships between the last two and NBSK prices, and between the product prices themselves. As should be expected for market-priced commodities, the price forecasts are far from perfect. However, as table 3-11 shows, only three of the 22 models made more forecasts to the opposite direction of price movement than the correct direction. Especially pulp models between 3 and 18 months do a relatively good job forecasting more than three out of four price movement directions. By looking at these figures, the long term models for uncoated magazine paper and newsprint can be deemed useless. Of course, the short time period used in these calculations does not allow any definite conclusions about the goodness of the models.

Table 3-9: Percentage of correct direction of real price change forecasts between the first forecast made in February, 1993 and February, 1997 for models re-estimated each month

Model	NBSK	Uncoated Fine Paper	Uncoated Magazine Paper	Newsprint
1	65.2 %			
2	71.7 %			
3	77.8 %	63.0 %	80.4 %	80.4 %
4	80.0 %			
5	88.6 %			
6	88.4 %	65.1 %	60.5 %	60.5 %
9	80.0 %			
12	89.2 %	78.4 %	51.4 %	40.5 %
18	77.4 %			
24	56.0 %	64.0 %	24.0 %	44.0 %

The ability to forecast the direction of price movements, albeit having some value on its own, is not enough for most purposes. If the actual forecast prices are also to be used, the magnitude of the expected forecasting error is of great interest. Although the confidence levels presented earlier give a view on the issue, it can also be measured with the coefficient of determination, which was also shown for each model.

While the idea behind the figures in table 3-12 is the same as before — looking at the ratio of the width of the forecast error's distribution and the width of the price change's distribution — the negative numbers may seem strange. The unrestricted OLS regression works in a way where the (unadjusted) coefficient of determination is always between 0 and 1. The *ex-ante* forecasts may, however, be so wrong that the error variance becomes greater than the variance of the forecast variable.

Table 3-10: Forecasting efficiency (coefficients of determination) of real price change forecasts between the first forecast made in February, 1993 and February, 1997 for models re-estimated each month

Model	NBSK	Uncoated Fine Paper	Uncoated Magazine Paper	Newsprint
1	0.373			
2	0.441			
3	0.508	0.386	0.426	0.460
4	0.583			
5	0.629			
6	0.655	0.147	0.010	0.166
9	0.577			
12	0.500	0.284	-0.096	-0.450
18	0.058			
24	0.043	-0.527	-1.307	-0.829

If the forecasts were perfect, the figures in table 3-12 were equal to 1. A negative number means that the forecast error variance is greater than the price change variance, and thus the forecasts hardly bring any additional information about the future.

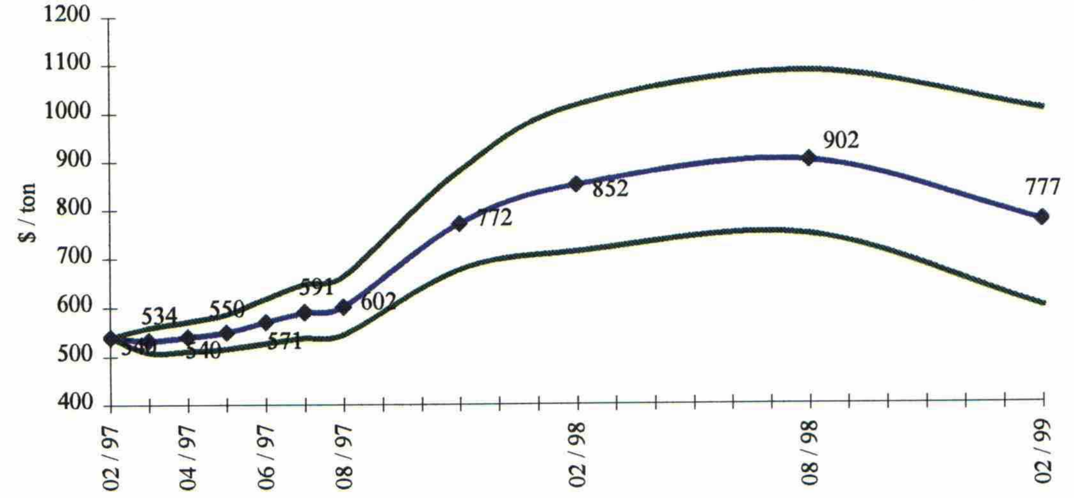
The figures show that pulp models for up to twelve months and three month paper models did actually predict a large part of price changes between March, 1993 and February, 1997. The best model seems to be the six-month pulp model. Pulp models for 18 and 24 months and paper models for 6 to 24 months (except the 12-month UFP model) did not prove useful. Again, however, the shortness of the evaluation period must be taken into account.

3.4 Forecasts in February, 1997

The actual forecasts made by the final models are converted from logarithmic changes to dollars with equation 3-2 (see p. 31) and presented in figures 3-32 to 3-

36. The 95% confidence levels also shown are again calculated based on the assumption that the distributions and correlation of the variables remain the same during the forecasting period. Moreover, the dollar figures are real prices expressed in February, 1997 dollars, and thus include no inflation adjustments. If the U.S. producer price index would be expected to rise, e.g., 2% a year, the 12 and 24 month actual dollar price forecasts should be approximately 2% ($10-$20) and 4% ($20-$40) higher, respectively.

Figure 3-32: NBSK pulp real price forecasts in February, 1997, and 95% confidence levels



The NBSK forecast shows a small drop in price in March, and then a slow but steady rise until August. In the autumn, NBSK price is expected to rise substantially and remain in a higher-than-average level for the rest of the 24-month period, peaking at approximately $900 in August, 1998. The confidence level range widens substantially between six and twelve months, but the lower confidence level is still at approximately $700 between November, 1997 and August, 1998.

Figure 3-33: Uncoated fine paper real price forecasts in February, 1997, and 95% confidence levels

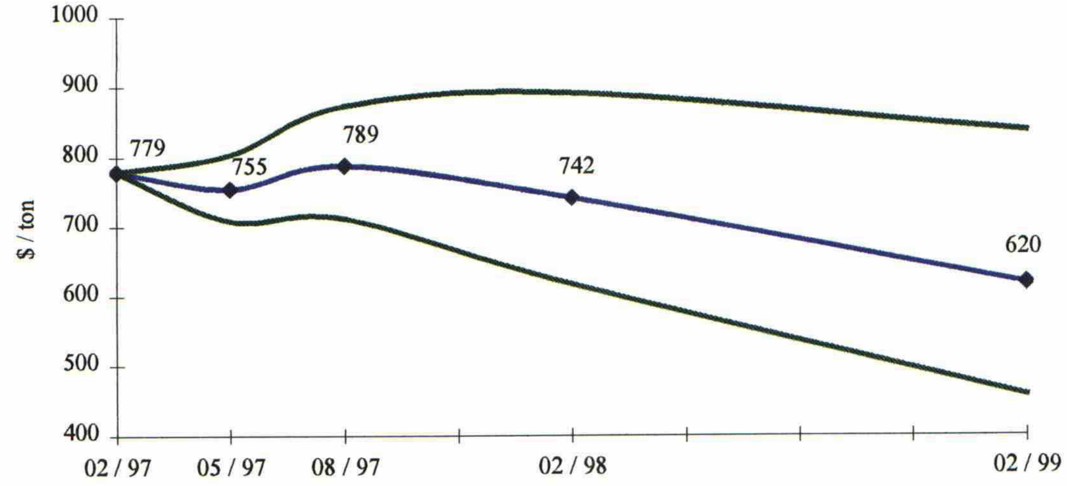
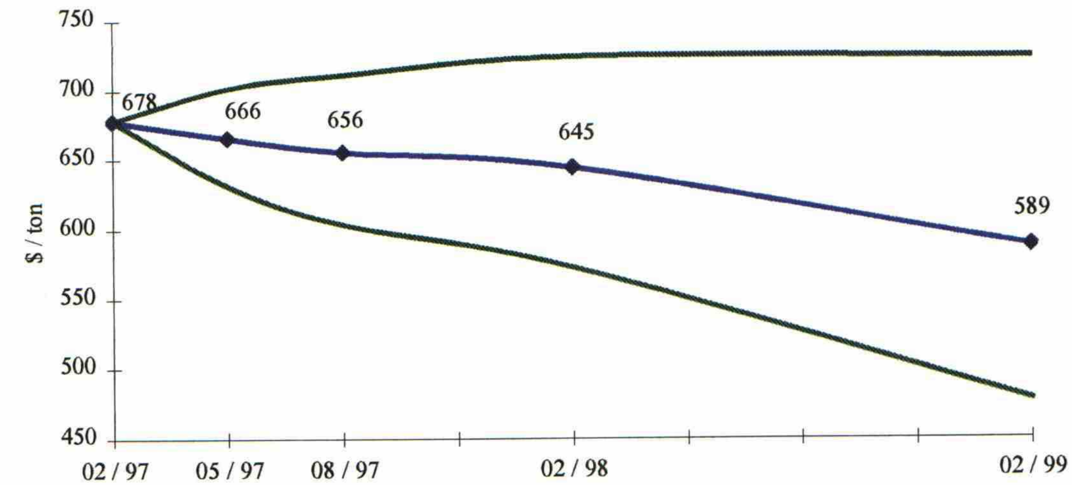


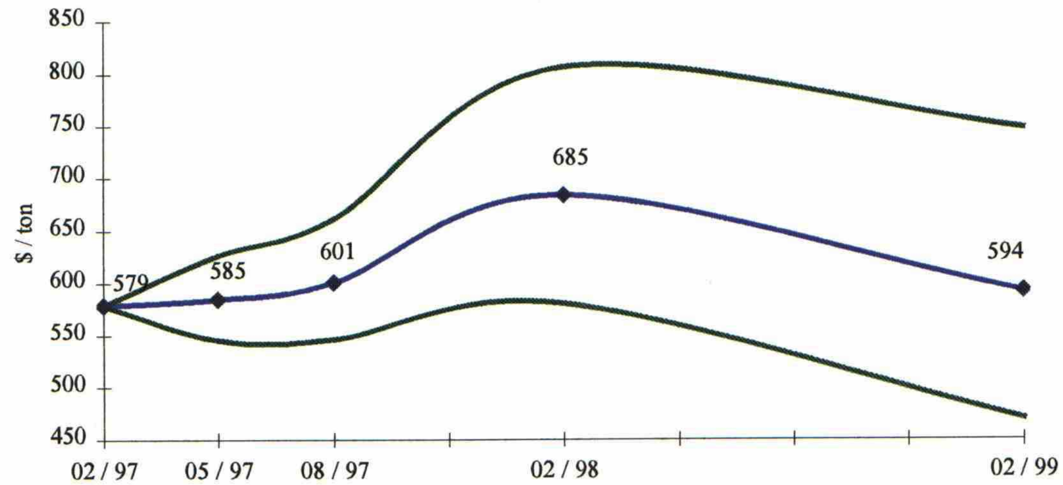
Figure 3-34: Uncoated magazine paper real price forecasts in February, 1997, and 95% confidence levels



The uncoated fine paper model predicts a slight drop in price before May and then a rise back to the February level in August. The longer term forecasts are, from the producers' viewpoint, pessimistic, forecasting prices to fall after the first six months. The confidence level range is, however, wide enough to cover prices of up to $850-$900 in the longer periods.

Also uncoated magazine papers are predicted to fall. The downhill shown in figure 3-34 is very steady, but the confidence level range is also wide, implicating the uncertainty of the forecasts.

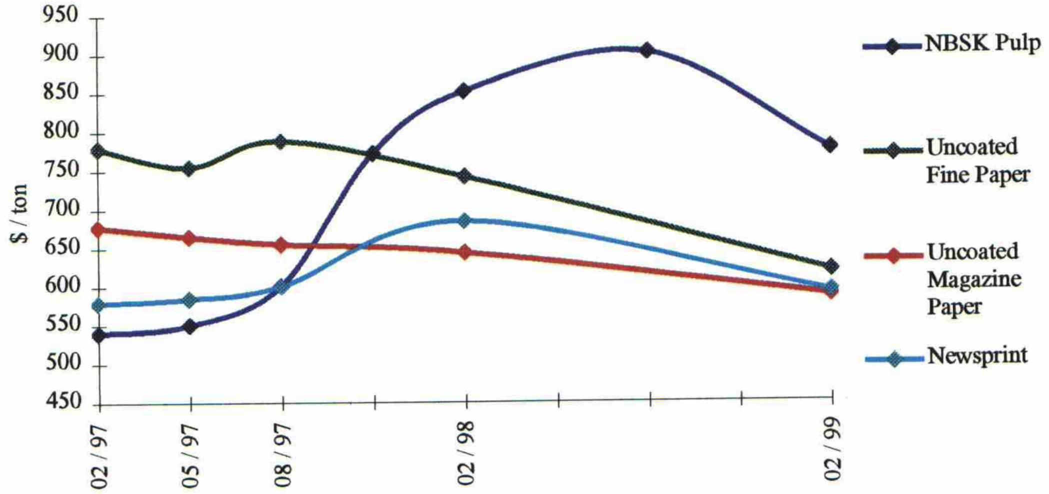
Figure 3-35: Newsprint real price forecasts in February, 1997, and 95% confidence levels



The newsprint model forecasts a rise in prices during the first twelve months and then a drop back to the start level in two years. The widest confidence level of all models allows for large deviations from the forecasts, though.

In figure 3-36, all models' forecasts are shown simultaneously. The first six months seem realistic, as only uncoated magazine paper misses the slight upward price trend in pulp and paper prices. The 12 and 24 month forecasts, however, are all but impossible. As the preliminary analysis showed (see figure 3-12, p. 42), uncoated fine paper price has never fallen below NBSK pulp price, and even though uncoated magazine paper and newsprint have often been cheaper than pulp when pulp prices have peaked, it is hard to believe that paper prices would continue to fall if pulp prices were to rise as strongly as predicted.

Figure 3-36: NBSK pulp, uncoated fine paper, uncoated magazine paper and newsprint real price forecasts in February, 1997



Therefore, as discussed also earlier in chapter *3.3.7 Overview of the Models,* the long term forecasts are rather unreliable. As already stated, pulp forecasts up to twelve months seem more trustworthy than paper forecasts, so in a conclusion the long term paper forecasts, especially those of uncoated fine paper and uncoated magazine paper, should be used with caution.

4 PULP DERIVATIVES

4.1 Basic Derivatives Theory

To utilise a view on where pulp and paper prices are heading, pulp and paper producers and buyers may use derivatives. The basic theory of three of the most common derivative instruments, forward and futures contracts and options, is given below.

4.1.1 Forward and Futures Contracts

As defined by Hull (1993, p. 2), a forward contract is

> … an agreement to buy or sell an asset at a certain future time for a certain price… One of the parties to a forward contract assumes a *long position* and agrees to buy the underlying asset on a certain specified future date for a specified price. The other party assumes a *short position* and agrees to sell the item on the same date for the same price. The specified price … [is] the *delivery price*. At the time the contract is entered into, the delivery price is chosen so that the value of the forward contract to both parties is zero.

The contract is settled at maturity. The holder of the short position delivers the underlying asset to the holder of the long position and is paid the delivery price. At delivery, if the spot price of the underlying asset is higher than delivery price, the holder of the long position gains. If the spot price is lower than delivery price, the holder of the short position gains. Forward contracts are usually over-the-counter (OTC) contracts; each contract is tailor made for the parties.

World-wide, forward contracts are seldom traded on an exchange. Futures contracts, however, generally are. Futures contracts normally differ from forward contracts in three fundamental aspects; (1) standardised contract features are specified by the exchange, improving the liquidity of the contract, (2) the exchange provides the parties a guarantee that the contract will be honoured, and (3) the contracts are marked to market usually each trading day. The guarantee comes from the fact that the exchange is a counterparty for every short and long position in the markets, holding no position itself i.e. having equally many short and long positions, so the investor's risk of the other party not honouring the agreement is extremely small. Marking to market means that each investor is required to deposit funds, an initial margin, in a margin account when the contract is made. Then, depending on whether the futures price goes up or down and whether the investor has a short or long position, he or she either must deposit more money to the margin account or may withdraw money from it. The margin account reflects the investors gain or loss from the contract, and daily marking to market serves to avoid big losses left unpaid.

The delivery price of a forward or futures contract depends on the spot price of the underlying, interest rates, time to maturity, and factors affecting the value of the underlying such as dividends. For commodities, two important such factors are storage costs and the benefits from owning the physical commodity. The benefits are sometimes referred to as the convenience yield. The interest that is paid to finance the asset less the income earned on the asset plus the storage cost is known as the cost of carry. (Hull 1993, pp. 65-69)

In Finland and some other countries, however, the contracts traded on derivatives exchanges have features of both forward and futures contracts. The contracts are essentially futures contracts with no initial margin nor marking to market. Instead of a set initial margin, they do have a margin requirement, which is based on a set of predetermined variables' values at the time the contract is entered. Additional margins are required only when needed. No marking to market means that if an investor's contract is in-the-money, i.e. the investor is "winning", he or she may not withdraw any of the winnings before expiry, even though the in-the-money contracts may be used to offset margin requirements from other contracts. Furthermore, physical delivery of the underlying asset is not necessarily made; the contract is often settled in cash (e.g. FIM Bond Futures on SOM).

4.1.2 Options

Like forward and futures contracts, options are about buying or selling in the future. However, the holder (buyer) of an option has a right to buy (a call option) or sell (a put option) at a set price (strike price), but no obligation to do so. The writer (seller) has an obligation to buy or sell at the maturity of the option (European options) or at any date before maturity, if the holder should exercise the option (American options).

Margin requirements only apply to the writer of the option. The contract price is always positive, depending on the current spot price and expected future volatility of the underlying, expiration date, delivery (strike) price, interest rates, and factors affecting the value of the underlying such as dividends. Examples of some widely used valuation models are the Black and Scholes, Garman-Kohlhagen, Black (also denoted Black 76), and binomial models.

4.2 Pulp Derivatives on Trade

The latest attempts to launch pulp derivatives are the ones made by the Finnish Options Exchange (FOEX) and PULPEX, a subsidiary of the Swedish OM. At the time of writing, it is too early to say anything definite about their future and whether pulp derivatives will become liquid enough. The main difference between the products of these two companies is the way of settlement, which on FOEX is (usually) done by cash and on PULPEX by physical delivery. Competition will, hopefully, be to the advantage of all parties, and it is possible that both exchanges will generate enough volume for active markets, as the products are slightly different. "The trend is very clear in the United States, where old delivery based commodity contracts are currently being replaced by cash settlement", states Anders Lindeberg of FOEX (FOEXpress 1/97), while on PULPEX's material (http://www.PULPEX.com) it says that "physical-delivery settlement is clearly superior to cash settlement for pulp futures." The products of both are explained below.

4.2.1 Pulp Derivatives Traded on FOEX

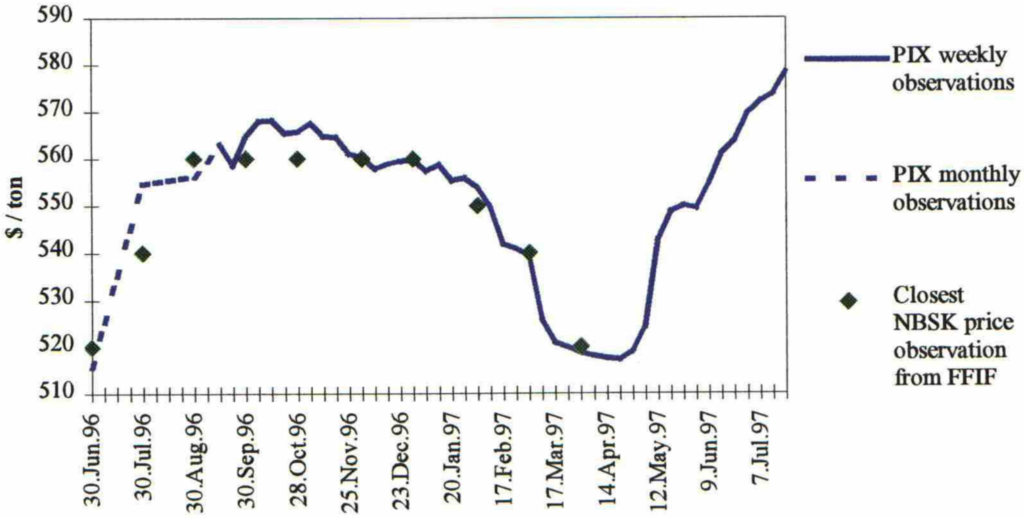
FOEX opened markets for derivatives based on NBSK pulp on February 4, 1997, after several cancelled trials. Both futures and options are available, and they are usually settled in cash. Options are usually European but may be also American, and by an agreement between the buyer, seller, and FOEX, the delivery of a futures or options contract may be made by physical delivery. The underlying of each contract is 50 tonnes of NBSK pulp as defined more explicitly in the contract specifications (see Appendix 2).

The cash settlement is based on the PIX Index calculated and published weekly by FOEX. The index is calculated the following way (FOEX Exchange Statutes): The latest three deals' prices for NBSK deals of a minimum of 100 tonnes are collected from sellers, buyers and agents (approx. 50 in total). The NBSK traded must comply with the definition given in product descriptions. Then, the highest 10% and the lowest 10% of the collected prices are discarded. The index value and also the settlement price are the arithmetic average of the remaining prices.

The PIX Index from its start is shown in figure 4-1. The NBSK price observations from FFIF used in forecasting are also presented. The two values are reasonably close to one another, the difference being less than 2% before November, 1996, and less than 0.5% since that month. The credibility of the index is essential for the markets to develop, as derivatives are "leveraged" instruments and a small change in settlement price may have a large effect on the profit or loss of a contract. Even though the views of FFIF and PIX on pulp price have been effectively the same after November, 1996, some parties do question the index's correctness. Unfortunately, as spot pulp is not traded publicly on a market place and qualities vary, there can not be a price that would satisfy all parties.

Trading at FOEX has started very slowly. On July 22, 1997, open interest on NBSK futures was five contracts for series ending in September, 1997, and zero contracts for the January, 1998 series (http://www.foex.fi). No trading had taken place on that day.

Figure 4-1: PIX pulp price index and NBSK price from FFIF June 30, 1996 - April 1, 1997 (sources: FOEX and FFIF)



4.2.2 Pulp Derivatives Traded on PULPEX

PULPEX launched their NBSK pulp options and futures on May 29, 1997. The underlying of each contract is 24 tonnes of NBSK pulp more explicitly described in contract specifications (see Appendix 3). As opposed to FOEX's derivatives, settlement is made by physical delivery. The delivery months are March, June, September and December. In addition, such other months are delivery months that the next two months are always available for trading.

PULPEX's pulp options are actually options on futures, i.e. their underlying is not the physical pulp but the futures contract for the same delivery month. This is not as unusual way to trade options; commodity futures are actually more common than options on commodities directly. The reason is that it is often cheaper to deliver the futures contracts on the asset than the asset itself (Hull 1993, p. 259). The cash settlement made at expiration is based on the difference of the option's strike price and the settlement price of the futures contract. The futures contract has zero value and can be closed at will.

Since only approximately 20% of world pulp production is market pulp, and most pulp users want very precisely defined pulp for their paper machines, it is impossible to trade all pulp via an exchange. However, it is still possible to use derivatives with physical delivery, as long as the position can be closed out at a reasonable price before expiration and delivery. In oil futures, the largest commodity futures market of the world, for example, only 1-3% of contacts are held to maturity (Banks 1987). However, if the market is illiquid, it may be hard to close a contract for a reasonable price. This is especially true if one has a large portion of the current open interest (number of contracts not closed with offsetting contracts). For PULPEX, establishing enough volume and liquidity is thus most important. So far, volumes have been modest. On July 22, 1997, the trading statistics were as follows (www.PULPEX.com):

Futures:

MONTH	BID	ASK	LAST	HIGH	LOW	VOLUME	OPEN I.	USD 000's
SEP 97	546.00	552.00	549.00	554.00	549.00	45	139	596
DEC 97	552.00	558.00	552.00	557.00	552.00	27	91	360

Call Options:

MONTH	PRICE	BID	ASK	LAST	HIGH	LOW	VOLUME	OPEN I.
SEP 97	550	14.00	20.00	--	--	--	0	4
SEP 97	600	22.7*	22.9*	--	--	--	0	2

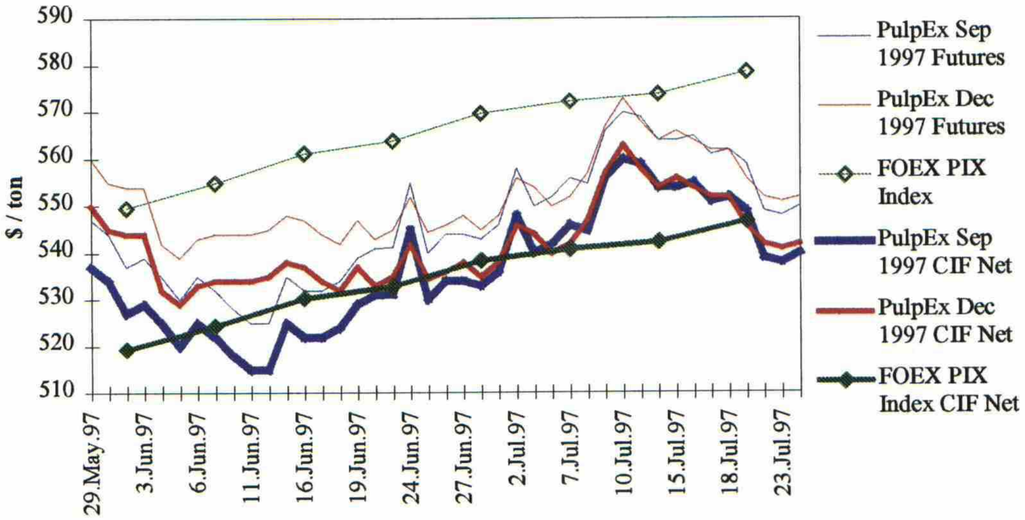
In put options, there was neither open interest nor any trading. The open interest in futures is, however, a lot larger than FOEX's, 230 contracts to 5, even though the PULPEX contract is only about half of FOEX's contract in size. The total volume of 72 contracts, if scaled to tonnes per year, is approximately 0.2% of yearly pulp production, and less than 1% of yearly market pulp production. In comparison, crude oil futures trading on New York Mercantile Exchange (NYMEX) represents approximately 150% of yearly crude oil production (Banks 1992), and trading in aluminium futures is said to be dozens of times larger than production.

The settlement prices (price of last trade) for both open futures series are shown together with respective PIX Index values in figure 4-2. When comparing these figures, it must be taken into account that the PIX Index is based on prices before any reductions CIF West Europe, while the PULPEX delivery translates into a net price of pulp already in a warehouse in one of the named West European ports. The normal price reduction from list price is estimated to be 5-6% and the savings from having pulp already in a warehouse instead of in a ship $10/ton (Yrjö-Koskinen July 30, 1997). The PIX Index CIF net value is thus calculated as 95.5% of PIX Index, and the PULPEX settlement prices CIF net are calculated by subtracting $10 from the original figure.

Theory expects futures prices to converge towards spot prices until they are equal at maturity. The futures prices in the figure, however, range from 98% to 105% of respective PIX Index values (spot price) using CIF net figures. Assuming PIX Index is a good measure of spot price, the basis risk (the uncertainty associated with the difference between spot and futures prices (Hull 1993, pp. 34-36)) is quite large. The low volumes explain the shifts in basis at least partly. On the other hand, PIX price information may in parts be as old as two weeks, hence causing the index to lag behind when prices move swiftly.

It is also important to note that the futures prices have, on average, been at the same level as the spot price, PIX Index. This does not necessarily mean that markets expect pulp price to stay the same in the future, but may also relate to the convenience yield and cost of carry explained earlier. For financial securities that provide no income (such as a non-dividend paying stock), futures prices are expected to equal the current spot price plus risk-free interest, i.e., to be above the spot price. For commodities, storage costs are added to the risk-free interest, and convenience yield is subtracted from it. Thus, for futures prices to be at spot prices, the convenience yield should equal the risk-free interest rate plus storage costs. However, as the PIX Index certainly reacts slower to new information than futures, the fact that the futures prices are at the same level as PIX Index may also be due to futures prices forecasting future spot prices. (Hull 1993, pp. 68-69)

Figure 4-2: PULPEX NBSK futures settlement prices between May 29, 1997 and July 24, 1997 for September and December series and FOEX's PIX Index values (sources: http://www.PULPEX.com and http://www.foex.fi), and all three converted to CIF net prices



4.3 Hedging Using Pulp Derivatives

According to Hull (1993, p. 12), the traders of derivatives can be categorised as hedgers, speculators, or arbitrageurs. Arbitrageurs in pulp derivatives may seek riskless profits from relative mispricing of the derivatives themselves; as the underlying asset is not actually easily tradable, arbitrage using the underlying asset and derivatives is difficult. Speculators, on the other hand, think they know what the price will be in the future, and place their investments accordingly.

Hedgers, on the other hand, are interested in reducing the risk that they already face. Forwards, futures, call options and put options can all be used to hedge from price changes either by themselves or in combinations. The simplest hedge is a forward contract, where the price of a future deal is set at the time the contract is made. However, to be able to define the contract that accurately, the hedger must find some other party who wants to take the opposite side. This may be difficult, and so would be getting rid of the hedge before expiry. Exchange traded derivatives provide liquidity and reduce counterparty risk, but because of the necessary standardisation, the contracts are not fully equivalent to all hedgers' needs.

A company that knows it is due to sell an asset at a particular time in the future can hedge by taking a short futures position, i.e. selling futures contracts. This is called a short hedge. If the price of the asset goes down, the value of the futures contract goes up, and vice versa. Similarly, a company that is to buy the asset takes a long futures position - a long hedge. It is important to understand that the expected overall financial outcome is the same as before (except for transaction costs), but its volatility is smaller. (Hull 1993, p. 33)

If the futures contract incorporates physical delivery at settlement, and physical delivery is inconvenient or expensive to the hedger, the futures contracts must be closed before expiry. To have sufficient liquidity (in the form of open interest), the contracts are to be closed well before expiry. Closing a contract means buying a similar contract if it had been sold earlier and vice versa. For example, if a company had shorted 500 PULPEX NBSK December futures in August at the price of $550 (to hedge against pulp price fall) and wishes to avoid physical delivery, it should buy 500 PULPEX NBSK December futures in, say, November. Suppose the price in November is $530. Before November, the margin account of the company will be credited or debited according to pulp price movements . In December, the company has agreed to sell 500 x 24 tonnes delivered to one of the defined warehouses for $550 x 500 x 24, and to buy 500 x 24 tonnes delivered to one the warehouses for $530 x 500 x 24. It would, of course, make no sense to both deliver the pulp and receive it from someone else, so no pulp deliveries are made. Just the difference of the agreed buying and selling prices, $(550-530) x 500 x 24 = $240,000, is payable to the company. This amount has, however, already changed hands as margin account transactions.

Hull (1993, p. 36) recommends the use of a series expiring as close as possible to, but later than, the expiration of the hedge to have sufficient liquidity for closing the hedge. For example, if expiration months are March, June, September, and December, the March contracts would be used for hedges expiring in December, January, and February.

Sometimes the desired end of the hedge is later than the expiration dates of all available futures contracts. The hedger must then roll the hedge forward by closing one futures contract and taking the same position in a contract with later expiration date. This strategy involves additional risks, however; as there are equally many basis risks as there are separate contracts, and there is uncertainty about the difference between the two futures prices at rolling time. Also, when the contracts expire, the hedger must pay any amount lost in the hedge, while he or she may not have received any cash flow from the asset being hedged.

Options may be used in hedging by buying put options and/or writing call options. Bought put options cost money and thus cause the median result to be lower than before, but they limit the downside risk, while written calls generate cash flow and raise the median result and limit the upside potential. The two positions may be joined to form a combination, which is cheaper than just buying a put (but limits upside potential) and gives better downside protection than just writing a call (but does not generate as much cash flow). The strike price of the options may be chosen to be at the desired level, if such a series is available, but it should be remembered that usually the at-the-money options (strike price is close to spot price) are the most liquid. Otherwise, the considerations presented above for futures contracts apply also to options.

4.4 Optimal Hedge Ratio for NBHK Pulp and Paper Grades

Hedge ratio is defined by Hull (1993, p. 37) as "the ratio of the size of the position taken in futures contracts to the size of the exposure". Hedge ratio depends on company policy, as companies seek the optimal ratio of exposure and hedging costs. However, even when the target is to minimise risk, a hedge ratio of 1.0 is not necessarily optimal. Similarly, when targeting a specific exposure, to simply use 1.0 less or plus the desired exposure as hedge ratio may lead to unwanted results.

As shown by Hull (1993, p. 38), the hedge ratio is calculated as follows:

First define

ΔS = Change in spot price, S, during the life of the hedge
$\Delta \mathrm{F}$ = Change in futures price, F, during the life of the hedge
σ_S = Standard deviation of ΔS
σ_F = Standard deviation of ΔF
ρ = Coefficient of correlation between ΔS and ΔF
h = Hedge ratio

When the hedger is long the asset and short futures (e.g., a pulp producer hedging pulp prices), the change in the value of the hedger's position during the life of the hedge is

$$\Delta S - h\Delta F \tag{4-1}$$

For the opposite case, short the asset and long futures (e.g. paper buyer hedging paper prices) it is

$$h\Delta F - \Delta S \tag{4-2}$$

In both cases the variance of the change in value (denoted v) of the hedged position is

$$v = \sigma_S^2 + h^2\sigma_F^2 - 2h\rho\sigma_S\sigma_F \tag{4-3}$$

which is at minimum (since $\frac{\partial^2 v}{\partial h^2} > 0$) when

$$\frac{\partial v}{\partial h} = 2h\sigma_F^2 - 2\rho\sigma_S\sigma_F = 0 \tag{4-4}$$

Solving equation (4-4) for h,

$$h = \rho \frac{\sigma_S}{\sigma_F} \tag{4-5}$$

When the asset hedged is the underlying of the contract, like NBSK pulp is of the derivatives presented earlier, ρ=1 and $\sigma_F=\sigma_S$, and the optimal hedge ratio h=1.0. But, if other assets or a portfolio of assets are to be hedged with NBSK derivatives, the hedge ratio giving the least exposure is not equal to 1.0. The optimal hedge ratios for NBSK and NBHK pulp and the five paper grades are presented in table 4-1.

Table 4-1: Optimal hedge ratios for NBSK pulp, NBHK pulp, uncoated and coated fine paper, uncoated and coated magazine paper, and newsprint for three and twelve month hedging periods

	3 months	**12 months**
NBSK Pulp	1.000	1.000
NBHK Pulp	1.114	1.106
Uncoated Fine Paper	0.554	0.733
Coated Fine Paper	0.338	0.528
Uncoated Magazine Paper	0.199	0.304
Coated Magazine Paper	0.221	0.375
Newsprint	0.223	0.366

The hedge ratios assume that NBSK futures have the same standard deviation and the same correlation coefficients as NBSK pulp. When adequate data is available, these figures may be estimated directly, but the assumption is eligible, if pulp futures prices are theoretically correct. The optimal hedge ratio may depend on hedging period, because the correlation between variables varies. In this case, correlations are stronger (closer to one) for the longer periods. Also standard deviations vary, but their influence in this case is smaller.

As a practical example to clarify the use of the hedge ratios, assume that a pulp buyer needs to buy 10,000 tonnes of NBHK pulp twelve months from now. The buyer wishes to minimise the variance of the change in the actual price the pulp is bought and today's price, i.e., minimise the exposure to price risk. The correct number to buy FOEX futures (contract size 50 tonnes) expiring 13 months from now is

1.106 x (10,000 / 50) = 221 contracts. The respective number of PULPEX contracts (contract size 24 tonnes) would be 461 contracts. Since NBHK price movements tend to be larger than NBSK price movements, a larger number of contracts is required, even though the correlation between the two is not perfect. The hedge is not perfect, either, but since the correlation is very high (0.93), it can be trusted to give fairly good protection against price rises.

For uncoated magazine paper hedge for twelve months, the hedger would use approximately three contracts per each ten contracts he or she would use to hedge NBSK pulp, as the hedge ratio is approximately 0.3. However, since the standard deviation of newsprint price changes is about two thirds of that of NBSK (see table 3-3, p. 45), the hedge is necessarily further from perfect. In any case, it gives partial protection to the hedger.

For combinations of assets, the optimal hedge ratio is simply the weighted arithmetic average of the individual hedge ratios, since

$$h_{xA+yB} = \rho_{xA+yB,F}\frac{\sigma_{xA+yB}}{\sigma_F} = \frac{\sigma_{xA+yB,F}}{\sigma_{xA+yB}\sigma_F} \times \frac{\sigma_{xA+yB}}{\sigma_F} = \frac{\sigma_{xA+yB,F}}{\sigma_F^2} =$$

$$= \frac{x\sigma_{A,F}}{\sigma_F^2} + \frac{y\sigma_{B,F}}{\sigma_F^2} = x\rho_{A,F}\frac{\sigma_A}{\sigma_F} + y\rho_{B,F}\frac{\sigma_B}{\sigma_F} = xh_A + yh_B \qquad (4\text{-}6)$$

using notation as earlier with S being divided to A and B with respective weights x and y and h_k denoting the hedge ratio for asset k.

As another example, assume that a forest company is due to buy 10,000 tonnes of NBSK market pulp and 8,000 tonnes of NBHK market pulp (its own pulp production being insufficient) and to sell 60,000 tonnes of uncoated fine paper and 50,000 tonnes of newsprint after twelve months. The "total tonnes sold" is therefore (-10-8+60+50) = 92 tonnes and the optimal hedge ratio

$$\frac{-10}{92} \times 1.000 + \frac{-8}{92} \times 1.106 + \frac{60}{92} \times 0.733 + \frac{50}{92} \times 0.366 = 0.472$$

The amount of futures contracts sold is 0.472 x (92,000 / 50) = 869 for FOEX futures or 0.472 x (92,000 / 24) = 1,809 for PULPEX futures. If the hedger were to hedge each position separately with FOEX futures, he or she would buy 200 contracts to hedge NBSK, buy 177 contracts (NBHK), sell 880 contracts (UFP), and sell 366 contracts (newsprint), equivalent again to selling 869 contracts. The company's own pulp production would be left without hedge, since it is both sold and bought. If, however, company units are relatively independent and wish to hedge their results, it may be done via exchange-traded derivatives. Of course, the transaction costs and margin deposits can be avoided by making the internal trade immediately (actually, this would be a forward contract between the company units).

The optimal hedge ratio may also be used in option trading in a similar manner. However, if the option's strike price is to be selected to reflect certain level of value of the underlying asset, adjustments to the strike price have to be made if hedge ratio does not equal 1.0. Suppose NBHK price is currently $600, and NBSK price is $650. To effectively hedge 50,000 tonnes of NBHK after 12 months to be worth at least $500 a ton, 1.106 x (50,000 / 50) = 1,106 FOEX put options should be bought. The correct strike price would be $650-(($600-$500)/1.106) ≈$560, since NBHK price is expected to move faster than NBSK (See Hull 1993, pp.251-253 for relating topics). Naturally, put options cost money and therefore the expected total value of the position is somewhat lower than $500 if pulp prices crash.

4.5 Derivatives and Forecasting

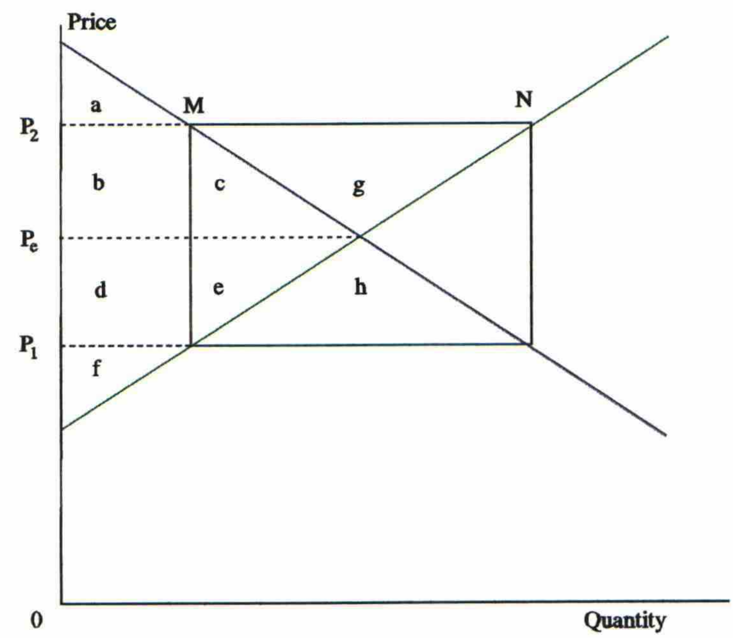
The impact of derivatives trading on the underlying asset's spot price variability (volatility) is of interest when derivatives trading is started. The hedgers prefer low volatility, while the speculators prefer high volatility. Even though the hedgers may use the derivatives markets in a similar manner as they would make long-term agreements among themselves (e.g. a pulp and paper producer sells futures, and a paper buyer buys futures), speculators are needed for the markets to function properly (Banks 1987). Speculators are willing to accept the risks the hedgers do not want; both parties will benefit from the redistribution of risk. Additional participants also provide more liquidity to the markets.

Since speculators can not participate in the physical (spot) markets, they have formerly had no role in pricing pulp. The relationship between speculation in commodity futures and price volatility, though, has long divided economists (Atsé 1986, p. 69). One view is that "destabilising" speculators must lose money, and therefore speculation should be stabilising to continue. According to Atsé, Johnson[7] presented the former argument as follows:

In figure 4-3, the demand and supply schedules are constant throughout the period and in equilibrium in the beginning (price = P_e). In the absence of speculators, the consumers' surplus is $a+b+c$ and the producers' surplus is $d+e+f$. If speculators who decide to buy the amount *MN* enter the market, prices rise to P_2, and the resulting surpluses are a (consumers) and $b+c+d+e+f+g$ (producers). The net effect of speculation is then $-(b+c)$ for consumers and $b+c+g$ for producers, an aggregate gain of g, which must thus be the loss of speculators. Identically, if speculators sell quantity *MN,* their loss is h. It follows then that destabilising speculators necessarily lose money.

7 See Johnson, H. G., "Destabilizing Speculation: A General Equilibrium Approach", *Journal of Political Economy*, 84, 1976.

Figure 4-3: Destabilising speculation; supply and demand curves and producer's and consumer's surpluses (source: Atsé 1986)



De Long *et al.* (1990) present the opposite view where noise traders (investors who irrationally act on noise as if were information that would give them an edge, also speculators) may actually earn higher expected returns because of their own destabilising influence. Since arbitrageurs have limited time horizons, they bear a risk of a further change of noise traders' opinion away from its mean (noise trader risk), as they may have to liquidate their positions before the price returns to the "correct" level.

The question as to whether speculation stabilises or destabilises commodity prices goes, however, beyond the issue as to whether profitable speculation is stabilising or whether destabilising speculation can be profitable. Firstly, speculation may continue even if speculators on average lose. One could argue that the less well-informed speculators who lose ("amateurs") are constantly replaced by equally less well informed others, who have overoptimistic belief in their information.

Secondly, the relation between speculative activities in the futures market and volatility of the spot market is not straightforward. Speculation in the futures market primarily affects the price of futures and the risk of inventory holding. If futures prices are stable, the propensity to hold inventories increases, which tends to stabilise spot prices, too. However, these changes may decrease the volume of transactions on the spot market and shift the supply or demand, thus affecting spot price. (Atsé 1986, pp. 71-72).

The arguments for and against speculation's destabilising effect include a law enacted by the U.S. Congress in 1958 prohibiting futures trading in onions because of it causing price fluctuations; a study by Milton Friedman arguing that profitable speculation is generally stabilising; Houthakker's conclusion that speculators had a stabilising effect on cotton prices; and Aliber's study that found neither stabilising nor destabilising effect on cotton[8]. (Atsé 1986)

One of the difficulties in studying whether derivatives trading affects price volatility is that the comparison must be made between "before derivatives" and "after derivatives". Since both periods must be long enough to enable reliable volatility measurement, there is no way to filter out all other factors affecting price volatility. However, it is easier to study whether futures markets are efficient. Efficiency means that there is no bias in futures prices that would make it possible to obtain positive returns from the use of this bias in speculating in the markets. Also, if futures prices are to be useful in forecasting futures spot prices, it is expected that there is no such bias.

Kumar (1991) found no systematic bias in crude oil prices. When forecasting oil prices, he also found that the futures prices were better predictors of future spot prices than time series models based on past prices; oil futures prices, therefore, contained additional information.

8 See Friedman, M., *Essays in Positive Economics*, Chicago, 1953; Houthakker, H.S., "Can Speculators Forecast Price?", *Review of Economics and Statistics*, XXXIX, 1957; Aliber, R.Z., "Speculation and Price Stability Once Again", *Journal of Political Economy*, LXXII, 1964.

In pulp markets, where there is no active spot trading and price information has to be gathered from market participants (e.g. the PIX Index), derivatives markets provide a way of "summing up" all participants expectations of prices in the future. These expectations are obtainable by all participants via public sources. Hence, pulp derivatives bring additional information to the markets, and also speed up the circulation of currently obtainable information. This may increase price volatility, since new information is included spot prices faster than before.

5 SUMMARY AND DISCUSSION

The recent steep ups and downs in pulp and paper prices have resulted in the need to (1) better understand the factors that affect pulp and paper prices, and (2) be able to protect from unfavourable price movements. This study has examined the factors in the form of creating forecasting models for NBSK pulp, uncoated fine paper, uncoated magazine paper, and newsprint prices. The recent attempts to start pulp derivatives trading, the derivatives on trade, and hedging strategies have been briefly examined.

The forecasting models generated perform relatively well during the test period of March, 1993 to February, 1997. Separate models for the short term (six months or less) and long term were generated. The pulp models clearly have forecasting power for up to twelve months, while the paper models' predicting power for longer periods than three months is questionable. This disparity is mostly due to the forecasting variables being pulp-based; for papers, quality differences are greater, and data of monthly production, inventories etc. not generally available. The forecasts made in February, 1997, showed a sharp rise in pulp prices in Autumn, 1997, while paper prices were predicted to fall at the same time. This highly unlikely scenario is probably due to the unreliability of long term paper price forecasts.

The technique used in forecasting was an OLS linear regression of logarithmic price change on lagged predicting variables. Co-integration of variables was included in the models, as the *Engle-Granger two-step procedure* suggests, as deviations from equilibrium state based on variable levels. Co-integration tests, however, found significant co-integration only between NBSK and NBHK pulp prices, even though many other variables were close to being statistically significantly co-integrated, such as NBSK inventories and price, NBSK deliveries and price, and different pairs of paper and pulp prices. The models were clearly not autocorrelated according to Durbin-Watson p-values calculated, but the Chow and Goldfeld-Quant tests produced mixed results of whether the models were structurally stable or heteroscedastic. A seven-year estimation period (84 observations) was chosen to limit the risk of including a structural change and on the other hand to include a large enough number of observations. A GARCH linear regression was tested for removing possible heteroscedasticity, but it yielded unstable models with worse performance than OLS models, and was thus rejected.

All variables used were carefully de-trended to separate real changes from e.g. growth of the pulp and paper production in general. The most important variables in most models were the 12 month change in OECD industrial production and the deviation of NBSK price from the estimated NBSK inventories / potential NBSK manufacturing capacity-based equilibrium price. In pulp and uncoated fine paper short term models, also short term changes in NBSK inventories and deliveries were included. Other included variables were of the co-integrating type.

Mostly, the co-integrating variables had negative coefficients, as expected, meaning that any disequilibrium had a tendency to return to equilibrium state. When several co-integrating variables were included in the same model, all statistically significant, some had positive coefficients. This instability was explained as being caused by complex relationships between the variables, leading to one "softening" the influence of others.

To summarise, rising OECD industrial production, falling NBSK inventories/PMC and rising NBSK deliveries/PMC forecast price rises for the products studied.

The two derivatives exchanges' (Finnish Options Exchange FOEX and PULPEX) products, their most important differences, and use in hedging pulp and paper prices was shortly discussed. Optimal hedge ratios for pulp and paper products were estimated; for NBSK, hedge ratio is 1.0 as the underlying of the derivatives contracts is also NBSK pulp; for NBHK, it is above 1.0; and for the paper grades, below 1.0. Hedging a portfolio of these products was also covered, the optimal hedge ratio then being the weighted average of the individual hedge ratios.

The pulp derivatives market will be an interesting research topic in the future. The pricing of contracts and the ways companies actually use derivatives may be researched, if and when the market develops and there are sufficient data available. It will be interesting to see how the competition for pulp derivatives markets turns out.

Appendix 1: Glossary

(source: Key to Finnish Forest Industry, FFIF)

Bleached Pulp	Pulp whose natural brightness has been improved using chemicals
Bleaching	Removal or modification of coloured components in pulp to improve brightness
Board	Thick, stiffish paper often consisting of several plies; widely used for packaging purposes
Chemical Pulp	Pulp in which wood fibres have been separated by chemical means
Coating	Process by which paper or board is coated with an agent to improve its brightness and/or printing properties
Dissolving Pulp	A chemical pulp grade used e.g. in the production of acetate and viscose fibres and cellulose films
Fine Paper	High-Quality printing, writing or copier paper produced from chemical pulp and usually containing under 10% mechanical pulp
Kraft Paper	High-strength paper made almost entirely of unbleached kraft pulp
Kraft Pulp	Unbleached sulphate pulp
Lightweight Coating	Coating applied at 7-10 g/m^2 on one or both sides of the paper

Lightweight printing paper	Printing paper with high bulk, grammage under 40 g/m^2, **LWC**
Magazine Paper	LWC or SC paper for printing magazines etc.
Market Pulp	Pulp produced for sale on the market (or for the producer's units abroad)
Mechanical Pulp	Pulp consisting of fibres separated entirely by mechanical means
Newsprint	Standardised printing paper produced from mechanical pulp; grammage 40-52 g/m^2
Pulp	Mechanically or chemically produced mass of fibre for production of paper and/or board
Sulphate Pulp	Chemical pulp produced by cooking wood in a liquor containing sodium hydroxide and sodium sulphide
Sulphite Pulp	Chemical pulp produced by cooking wood in a liquor containing sodium, magnesium, ammonium or calcium bisulphite
Supercalendered (SC)	Paper treated in a supercalenderer, usually uncoated magazine paper
Woodfree (paper)	Paper containing no mechanical pulp

APPENDIX 2: FOEX PULP DERIVATIVES PRODUCT DESCRIPTIONS

(source: www.foex.fi)

The PIX Pulp Price Index

The benchmark pulp price PIX is calculated by FOEX as defined in the Exchange Statutes. The price index reflects the current price of a fictive delivery conforming to the following minimum requirements:

- Price for amount over 100 tons prime quality Northern Bleached Softwood Sulphate Pulp
- Price for a regular customer, no credit risk assumed, for pulp to be delivered the following month
- Delivery terms CIF North Atlantic/North Sea port
- Payment term: 30 days net
- Price before possible rebates
- Standard dryness i.e. 90% air dry
- Standard strength characteristics
- Brightness 88 or higher (for standard ECF)

The fixing price is broadcasted on FOEX trading system and through major information services after 12.00 local time on the expiration day.

Contract specifications

Underlying commodity

NBSK

Contract size

50 metric tonnes

Minimum price movement

$1 per tonne for futures and forward contracts

Tick Size

$50

Instruments

European style call, put, future and forward contracts

Settlement

Cash USD, no delivery

Contract length

From 1 month up to 10 years

Expiration day

Last business Monday of the month

Counterpart

Clearinghouse FOEX

Expiration price

Pulp Price Index PIX

Trading hours

9.00 am - 5.00 pm local time

Quotations

Reuters: SOPI, Telerate 20948

APPENDIX 3: PULPEX PULP DERIVATIVES PRODUCT DESCRIPTIONS

(Source: www.pulpex.com)

Pulp Futures

Quality

Northern Bleached Softwood Kraft pulp (NBSK).

Contract Size

A standard delivery unit shall consist of 24 air dry metric tons of pulp, with an acceptable delivery of +/- 5%, consisting of a unit of 22.8 to 25.2 metric tons.

Transfer of ownership of pulp from seller to buyer will be carried out by a transfer of a warrant evidencing ownership of pulp in a designated warehouse.

Quality Parameters

The pulp should meet or exceed the following quality criteria in order to be eligible for delivery under the terms of a futures contract:

General Properties

- The NBSK pulp shall have been produced in Canada, Finland, Norway or Sweden.
- The pulp shall be a 'commercially traded' brand for which an up to date technical specification of the brand is freely available.
- The pulp shall be of prime quality, i.e. according to recognised industry standards, and free from contaminants, e.g. plastics or other foreign material.
- The pulp shall have been bleached using either an elemental chlorine free (ECF) bleaching process or totally chlorine free (TCF) process.
- The pulp shall have a moisture content less than 20% at the time of production.

- The maximum age of the pulp at the time of delivery under the terms of the contract shall be twelve months. A signed Production Quality Certificate should be presented as part of the delivery documents as proof of the pulp's age. Each bale should also bear a number or other identification mark to enable the time of manufacture to be determined.
- The dirt count of the pulp shall not be more than $6mm^2/kg$ air dry pulp.
- The brightness of the pulp shall be 88 % ISO or higher.
- The pulp shall meet the following strength properties at 25 Schopper Riegler or 500 Canadian Standard Freeness:

  Tensile Index not less than 80 Nm/g

  Tear Index not less than 9 mNm2/g

  Burst Index not less than 6 kPam2/g
- The level of DCM extractives in the pulp shall not be more than 0.1%

The pulp shall meet these general criteria when it is analysed under ISO approved test conditions.

Physical Condition

The pulp shall be in 'good physical condition' at the time that the warrant is delivered on the Delivery Day.

A description as to what constitutes 'good physical condition' will be set out in the OMLX exchange's rulebook.

Packing

The pulp shall be produced in sheeted form and shall be packed in standard export wrapped bales of declared uniform weight and air-dry content. The bales shall each weigh between 200 and 300 kilograms, strapped together in six, eight or sixteen bale units. Bales shall be tied with at least four strands of baling wire. Only full bale units will be acceptable for delivery, i.e. bale units may not be split.

Contract Currency

US Dollars

Minimum Price Movement

USD 0.25/metric ton

Par Value

DDU 'Designated Warehouse' Loaded on Truck (Incoterms 1990). This means that the seller pays all costs up to and including loading-out onto truck from the warehouse. DDU is a technical term and stands for 'Delivery Duty Unpaid'.

Delivery Locations

Delivery in OM exchange designated warehouses in Antwerp, Rotterdam and Terneuzen.

Delivery Months

On 29th May, only September and December 1997 delivery months will be listed.

Thereafter, contracts will be listed on a quarterly March-June-September-December expiry cycle. In addition such other months will be listed so that the nearest two calendar months are also available for trading. In total, therefore, five or six delivery months will normally be available for trading.

For example, in January 1998, the following delivery months would be available for trading: January, February, March, June, September and December. At the expiry of the January contract no new delivery month would be listed because the two nearest months -February and March - would already have been listed.

First Trading Day

The exchange shall list a contract for trading 12 months prior to the first day of the delivery month of that contract. For example, a September 1998 contract would be listed on the day after the Last Trading Day of the September 1997 contract.

Last Trading Day

The Last Trading Day in respect of a delivery month shall be the third Wednesday of such a delivery month.

Delivery Day

The Delivery Day shall be three business days after the Last Trading Day.

Daily Settlement Price

Last traded price on each business day.

Expiration Settlement Price

Trade weighted average price based on the last five trades on the Last Trading Day.

Expiration Settlement Amount

The Expiration Settlement Amount will be determined by multiplying the Expiration Settlement Price by the number of lots by the contract size.

Expiration Settlement Day

Delivery Day.

Trading Hours

Normally between 2pm and 5pm on UK business days.

Pulp Options

NB: The parameters set out above in respect of Quality, Contract Size, Quality Parameters, Packing, Contract Currency, Minimum Price Movement, Par Value, Delivery Months, Delivery Locations and Trading Hours apply equally to pulp options.

Contract Base

One pulp futures contract.

Exercise style

European style, i.e. options can only be exercised on the Last Trading Day.

Last Trading Day

The last trading day in respect of a delivery month shall be the tenth business day prior to the last trading day for the attendant futures contract.

Exercise Price Interval

Exercise prices shall be quoted at USD 25 intervals for the near two months and at USD 50 intervals for other expiry months.

Premium

Pulp options are premium up-front instruments, i.e. the premium is payable by the buyer to the seller on the business day following the trade (T+1).

Daily Settlement Price

Mid price of the closing bid and offer price. Where no closing price exists an OM exchange generated price will be used. These prices will be required for margin calculation purposes.

Expiration Settlement Price

Based on the Daily Settlement Price of the relevant futures contract.

Standard Exercise

Pulp options which are in-the-money at expiry, as defined by the Expiration Settlement Price, are subject to automatic exercise.

SOURCES

Atsé, D. 1986. Commodity Futures Trading and International Market Stabilization. *Studia Oeconomica Upsaliensia 10.* Uppsala.

Banerjee, A., Dolado, J. J., Galbraith, J. W., and Hendry, D. F. 1993. *Co-integration, error correction, and the econometric analysis of non-stationary data.* Advanced Texts in Econometrics. Oxford University Press, New York.

Banks, F. E. 1987. *Futures Markets, Options Futures Markets, and Oil Markets.* Working paper, Department of Economics, Uppsala University.

Banks, F. E. 1992. *Economic Theory and the Crude Oil Futures Market: A Summing Up.* Working paper, Department of Economics, Uppsala University.

Baudin, A., and Lundberg, L. 1985. *Saturation of Paper Demand - Myth or Reality?* Working paper, Fackföreningsrörelsens Institut för Ekonomisk Forskning, Stockholm.

Baudin, A., Nadeau, S., and Westlund, A. 1984. Estimation and Prediction Under Structural Instability: The Case of the U.S. Pulp and Paper Market. *Journal of Forecasting,* Vol. 3, pp. 63-78.

Bergman, M. A. 1993. Market Structure and Market Power: The Case of the Swedish Forest Sector. *Umeå Economic Studies No. 296*, University of Umeå.

Brännlund, R. 1989. Disequilibrium and Asymmetric Price Adjustment: The Case of the Swedish Timber Market. *Umeå Economic Studies No. 202*, University of Umeå.

Brännlund, R., and Löfgren, K-G. 1995. Cyclical Dumping and Correlated Business Cycles in Imperfect Markets: Empirical Applications to the Canadian Pulp and Paper Industry. *Applied Economics,* Vol 27, pp. 1081-1091.

Commercial Times, February 23, 1995, p.14. Imported paper getting pricier.

Dagens Industri, January 4, 1995, p. 7. Skogsbolag spar prislyft på massa och papper.

De Long, J. B., Schleifer, A., Summers, L. H., Waldmann, R. J. 1990. Noise Trader Risk in Financial Markets. *Journal of Political Economy,* 1990, Vol. 98, no. 4, pp. 703-738.

Engle, R. F., and Granger, C. W. J. (editors) 1991. *Long-run economic relationships: readings in cointegration*. Oxford University Press, New York.

Granger, C. W. J. 1980. *Forecasting in Business and Economics*. Academic Press, New York.

Granger, C. W. J. 1986. Developments in the Study of Cointegrated Economic Variables. *Oxford Bulletin of Economics and Statistics*, Vol. 48:3, pp. 213-229.

Granger, C. W. J., and Newbold, P. 1986. *Forecasting Economic Time Series*. Second Edition. Academic Press, New York.

Granger, C. W. J., and Watson, M. W. 1984. Time Series and Spectral Methods in Econometrics. In *Handbook of Econometrics Volume II* pp. 979-1022, ed. by Griliches, Z., and Intriligator, M. Elsevier Science Publishers, Amsterdam.

Greene, W. H. 1993. *Econometric Analysis*. Second Edition. Macmillan Publishing Company, New York.

Hull, J. C. 1993. *Options, Futures, and Other Derivative Securities*. Second edition. Prentice Hall Inc., New Jersey.

Johansen, S., and Juselius, K. 1990. Maximum Likelihood Estimation and Inference on Cointegration - with Applications to the Demand for Money. *Oxford Bulletin of Economics and Statistics*, Vol. 52:2, pp. 169-210.

Kauppalehti, July 15, 1996, p. 3. Paperiteollisuuden näkymät ristissä.

Kauppalehti, July 23, 1996, p. 7. USA:n metsäyhtiöiden tulosennusteet kohonneet.

Kauppalehti, July 5, 1996, p. 9. Sellun hinnan uskotaan nousevan 40 prosenttia tänä vuonna.

Key to the Finnish Forest Industry. Finnish Forest Industries Federation.

Kumar, M. S., 1991. *Forecasting Accuracy of Crude Oil Futures Prices.* IMF Working Paper.

Paper, November 1992, p. 26. Market Pulp. World: Market woodpulp inventories are piling up in face of excess capacity.

Strandström, T. 1996. A Test of the Arbitrage Pricing Theory on the Finnish Forest Industry Using Product Market Prices. *International Symposium on System Analysis and Management Decisions in Forestry Products, Valderia, Chile.*

Toppinen, A., Laaksonen, S., and Hänninen, R. 1996. Dynamic Forecasting Model for the Finnish Pulp Export Price. *Silva Fennica 30(4).* METLA, Helsinki.

White, K. J. 1993. *SHAZAM User's Reference Manual Version 7.0.* McGraw-Hill.

World Paper, March 1995, p. 4. Pulp leads the price path higher.

Zhang, D., and Binkley, C. S. 1994. The Informational Efficiency of the Vancouver Log Market and the Financial Risk of Holding Logs in Storage. *Canadian Journal of Forest Research,* Vol. 24, pp. 550-557.

Interviews

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